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Human Exposure to Atmospheric Concentrations of Selected Chemicals. Volume 2

Systems Applications, Inc., San Rafael, CA

Prepared for

Environmental Protection Agency
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16. ABSTRACT

EPA commissioned Systems Application, Inc.(SAI) to estimate, on a nationwide basis, public exposure to atmospheric concentrations of some forty chemicals. The purpose of the study was to provide EPA with information that would be helpful for determining which of the chemicals to study in more detail and in what order. The emphasis was on estimates that would support rough relative comparisons among the chemicals. There was no intent to define, by a scientifically defensible methodology, actual public exposure and actual ambient air concentrations; the purpose did not warrant the very heavy expenditure of funds that would be needed to carry our such a project. The study made free use of such techniques as algorithms for estimating emissions rather than actual emissions data, constructed plant locations rather than actual plant locations, simplified dispersion modeling to estimate ambient air concentrations, and a constructed "population" file that relied on extrapolation of 1970 Bureau of Census data on where people lived.

The original version of the report, dated May 6, 1980, was, in March 1981, made available for public review and comment. The current, and final, version of this report reflects the comments and data received and incorporated changes made to correct technical deficiencies, noted by SAI and EPA, in the previous version.

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Human Exposure To Atmospheric Concentrations Of Selected Chemicals

Volume II

Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

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ATTACHMENT A

HUMAN EXPOSURE TO ATMOSPHERIC CONCENTRATIONS OF SELECTED CHEMICALS

EPA Contract No. 68-02-3066

SAI No. 58-EF81-156R2

10 February 1982

Prepared for

Office of Air Quality Planning and Standards
Environmental Protection Agency
Research Triangle Park, North Carolina 27711

by

Systems Applications, Incorporated

Amended by EPA

to reflect public comments

APPENDICES

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The following three pages were located at the beginning of each appendix. In order to reduce the reproduction cost, all duplications of these pages have been removed. Thus, each appendix will begin on page four.

Each chemical was studied as one of a set of 35 chemicals. A complete description of the program is given in the parent document to this attachment. The table of contents of the parent report is presented as Figure 1 here. Specific questions that the reader may have about presentations in this attachment are most probably addressed in the relevant section or sections as described in Figure 1.

This attachment consists of the following elements:

- > A table of physical and chemical properties of the chemical.
- > A summary of emission sources, modes, and rates.
- > A map showing major, specific point sources.
- > Input parameters for dispersion calculations.
- > Exposure/dosage tables for each type of source analyzed and a summary for all sources.
- > A reference list for the emissions study.

A few definitions--described more completely in the main text--are presented here as an aid to the reader.

- > EXPOSURE - The number of people in the United States estimated to experience annual average atmospheric concentrations equal to or greater than the stated level.
- > DOSAGE - The sum over the population of the product of concentration ($\mu gm/m^3$), times number of people exposed at that concentration. This is a potential concentration, and does not represent material actually ingested or absorbed into body tissues.
- > EMISSIONS ANALYSIS - A review by one or more of various methods including surveys of literature or state and federal data, communication with, or visits to, staff of the operator of the sources to determine sources and source locations, and to estimate
  - emission rates-adjusted to 1978

- type of source (e.g. chimney, vent, open surface, etc).

> DISPERSION ANALYSIS - Use of a computer program to compute annual average concentration patterns given wind, turbulence and emissions data.

> POPULATION ANALYSIS - Use of a computer program to extract site-specific population patterns at the finest resolution available from U.S. Census Bureau 1970 census files. Populations are scaled to 1978 levels.

> SOURCE TYPE - Three source types are defined:

- Major, specific point sources, each emitting a significant fraction of the total emissions of a studied chemical. These sources are treated using parameters appropriate to each specific source.
- General point sources - other point sources warranting a detailed dispersion analysis but which are members of a group of sources too numerous to treat individually. For such sources, a prototype analysis is done, and results are multiplied by the estimated number of sources.
- Area Sources - sources which are so small and numerous that their concentration patterns are inseparable. Such sources are treated as emissions per unit area over identified areas.

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ACETALDEHYDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-07-0

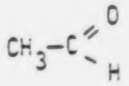
Synonyms: Acetic Aldehyde; Ethyl Aldehyde; Ethanal

Chemical Formula

Molecular Weight: 44.05

Molecular Formula: C_2H_4O,

Molecular Structure:



$CH_3{-}C\overset{O}{\underset{H}{\lessgtr}}$

Chemical and Physical Properties

Physical State at STP: Liquid - flammable, pungent odor

Boiling Point: 20.8°C at 760mm

Melting Point: -121°C

Density: 0.7834 at 18°C/4°C

Vapor Pressure: 923 Torrs at 25°C

Vapor Density: 1.52

Solubility: Infinite (hot H_2O)

Log Partition Coefficient (Octanol/H_2O): 0.43

Atmospheric Reactivity

Transformation Products: Peroxyacetyl Nitrate; Formaldehyde

Reactivity Toward OH·: 4 x Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: ≈ 0.5 x Formaldehyde

Major Atmospheric Precursors: Hydrocarbons (C_3 +)

Formation Reactivity: Equilibrium concentration ≈ 5% NMHC

I. SOURCES

A. PRODUCTION

Acetaldehyde (C_2H_4O) is produced by ethylene oxidation processes, such as the Wacker process, or by vapor phase oxidation and dehydrogenation of ethanol. The latter method has declined rapidly since the ethylene oxidation facilities have come on-stream. Publicker is the only company that uses the ethanol process.[1]

In the ethanol process, ethanol vapors and preheated air are mixed. The exit gases, containing ethanol and acetaldehyde, are scrubbed and the solution is rectified in a column to produce acetaldehyde. In the direct oxidation of ethylene, air or oxygen can be used. A water solution of cupric chloride and a small amount of palladium chloride is generally used as a catalyst. The gaseous reaction mixture containing steam and unreacted ethylene in addition to reaction product gases goes to a water scrubber, where acetaldehyde is removed in solution.[1]

There are currently four companies at five locations that produce acetaldehyde in the United States. The locations of the plants and the 1978 estimated capacity and production levels for each site are shown in Table 1-1.[1,2] An estimated 1000 million lb of acetaldehyde was produced in 1978.[1,2]

B. USES

Acetaldehyde is used exclusively as a chemical intermediate to produce other chemicals. The largest end-use is in acetic acid manufacture, which accounts for an estimated 690 million lb of production. The second largest end-use is for peracetic acid production, which consumed an estimated 100 million lb in 1978. Other uses of acetaldehyde include pentaerythritol (80 million lb), pyridines (40 million lb), glyoxal (40 million lb), 1,3-butylene glycol (20 million lb), and miscellaneous uses (remaining 30 million lb). There were no reported exports of acetaldehyde in 1978. Acetaldehyde end-uses are summarized in Table 1-2.[1,2]

Acetic acid is produced by two companies at three locations by the catalytic oxidation of acetaldehyde. Source locations are shown in Table 1-3.[3,4]

Table 1-1. Acetaldehyde Producers[a]

Company[b]	Location	1978 Capacity (10^6 lb/yr)	1978 Production[c] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bay City, TX	300	204	28 51 45/96 01 00
	Clear Lake, TX	600	408	29 37 17/95 03 51
Texas Eastman	Longview, TX	500	340	32 25 55/94 41 06
Publicker Industries	Philadelphia, PA	65	44	39 53 30/75 12 18
Shell Chemical	Norco, LA	5	4	30 00 11/90 23 42
Total		1470	1000	

[a] See refs. 1 and 2.

[b] Union Carbide shut down 200 million lb of capacity at Institute and S. Charleston, WV, in the first quarter of 1978.

[c] Total production distributed over individual sites based on site capacity compared to total industry capacity.

Table 1-2. 1978 Acetaldehyde End-Use Distribution*

End-Use	Usage (%)	Acetaldehyde Use (million lb/yr)
Acetic acid	69	690
Peracetic acid	10	100
Pentaerythritol	8	80
Pyridenes	4	40
Glyoxal	4	40
1,3-Butylene glycol	2	20
Miscellaneous	3	30
Total	100	1000

*See refs. 1 and 2.

Table 1-3. Acetic Acid Producers[a]

Company	Location	1978 Acetic Acid Capacity (10^6 lb/yr)	1978 Acetaldehyde Usage[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bay City, TX	110	68	28 51 45/96 01 00
	Clear Lake, TX	600	373	29 37 17/95 03 51
Tennessee Eastman	Kingsport, TN	400	249	36 31 27/88 32 29
Total		1110	690	

---

[a] See refs. 3 and 4.

[b] Total acetaldehyde usage distributed over all three sites based on acetic acid capacity.

Peracetic acid is manufactured by the liquid-phase catalytic oxidation of acetaldehyde at three sites in the United States. Source locations are shown in Table 1-4.[3]

Pentaerythritol is produced by the aldol condensation of acetaldehyde and formaldehyde in the presence of lime or caustic at ambient temperature and pressure. The four manufacturing sites are shown in Table 1-5.[3,5]

Synthetic pyridenes are produced as a co-product with beta-picoline by the vapor phase reaction of acetaldehyde, ammonia, and formaldehyde by two companies in the United States. Source locations are shown in Table 1-6.[3,6]

Glyoxal is produced by two companies by the nitric acid oxidation of acetaldehyde in an autoclave at two locations as shown in Table 1-7.[3]

1,3-Butylene glycol is produced by the catalytic hydrogenation of acetaldol which is made by the liquid-phase condensation of acetaldehyde. The three companies at three sites which produce 1,3-butylene glycol are shown in Table 1-8.[3]

II. EMISSION ESTIMATES

A. PRODUCTION

Acetaldehyde emissions from production sites are presented in Table 1-9.[7,8,9,10,11] Total estimated emissions from these sites for 1978 were 271,730 lb. Emission factors, derived from state files, used to develop process, storage, and fugitive emission estimates are shown in Table 1-9. Process vent emissions originate primarily from the off-air absorber vents. Other associated emissions would include ethylene and ethane. Storage emissions represent the losses from both working and final product storage tanks. Fugitive emissions are those which result from plant equipment leaks. For the purpose of this report, the emissions of acetaldehyde from the ethanol process used by Publicker were assumed to be the same (emission factor) since no data were available from that site.

Vent parameter data for the production sites[11] as well as the end-users are shown in Table 1-10.

Table 1-4. Peracetic Acid Producers[a]

Company	Location	1978 Peracetic Acid Capacity (million lb)	1978 Acetaldehyde Used (million lb)[b]	Geographic Coordinates Latitude/Longitude
FMC	Buffalo, NY	NA[c]	33.33	42 59 10/78 50 30
High Point Chemical	High Point, NC	NA	33.33	35 59 10/80 00 30
Union Carbide	Taft, LA	NA	33.33	29 58 00/90 27 00
Total		NA	100.00	

[a] See ref. 3.

[b] Total acetaldehyde used distributed evenly over all three sites in the absence of capacity data.

[c] Not available.

Table 1-5. Pentaerythritol Producers[a]

Company	Location	1978 Pentaerythritol Capacity (10^6 lb/yr)	1978 Acetaldehyde Used[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Celanese	Bishop, TX	75	33	27 34 06/97 49 27
Hercules	Louisiana, MO	47	21	39 26 24/91 03 37
IMC (CSC)	Seiple, PA	25	11	40 38 12/75 31 58
Perstorp AB	Toledo, OH	35	15	41 43 10/83 31 28
Total		182	80	

[a] See refs. 3 and 5.

[b] Total acetaldehyde usage distributed over all four sites based on pentaerythritol capacity.

Table 1-6. Pyridenes Producers[a]

Company	Location	1978 Pyridene Capacity[b] (10^6 lb/yr)	1978 Production[c] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Nepara Chemical	Harriman, NY	>25	17	41 16 45/74 08 24
Reilly Tar & Chemical	Indianapolis, IN	35	23	39 42 00/86 14 00
Total		>60	40	

[a] See refs. 3 and 6.

[b] Capacity includes pyridenes, picolines, and pyridene derivatives.

[c] Total acetaldehyde usage distributed over both sites based on pyridenes' capacity.

Table 1-7. Glyoxal Producers[a]

Company	Location	1978 Glyoxal Capacity (million lb)	1978 Estimated Acetaldehyde Used[b] (million lb)	Geographic Coordinates Latitude/Longitude
American Cyanamide	Charlotte, NC	NA[c]	20	35 12 16/80 50 32
Union Carbide	Taft, LA	NA	20	29 58 00/97 27 00
Total		NA	40	

[a] See ref. 3.

[b] Total acetaldehyde used distributed equally over both sites in the absence of capacity data.

[c] Not available.

Table 1-8. 1,3-Butylene Glycol Producers[a]

Company	Location	1978 1,3-Butylene Glycol Capacity (million lb)	1978 Acetaldehyde Used (million lb)	Geographic Coordinates Latitude/Longitude
Celanese	Bishop, TX	NA[c]	6.67	27 34 06/97 49 27
Eastman	Rochester, NY	NA	6.67	43 12 01/77 37 58
Mallinckrodt	Lodi, NJ	NA	6.67	40 52 56/74 05 46
Total		NA	20.00	

[a] See ref. 3.

[b] Total actaldehyde used distributed evenly over all three sites in the absence of capacity data.

[c] Not available.

Table 1-9. Acetaldehyde Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Celanese	Bay City, TX	46,510	5,915	2,650	55,080	0.79
	Clear Lake, TX	106,585	0	5,305	110,890	1.59
Tennessee Eastman	Longview, TX	77,520	9,860	4,420	91,800	1.32
Publicker Industries	Philadelphia, PA	10,030	1,275	570	11,880	0.17
Shell Chemical	Norco, LA	910	115	50	1,080	0.02
Total		241,560	17,170	13,000	271,730	

[a] Based on the following emission factors (lb acetaldehyde emitted per lb produced). See refs. 7, 8, 9, 10, and 11.

Process	0.000228	B - (derived from state air emission files)
Storage	0.000029	B - (derived from state air emission files)
Fugitive	0.000013	B - (derived from state air emission files)
Total	0.000270	

[b] Based on 8760 hr/yr operation.

Table 1-10. Acetaldehyde Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Distribution Area (ft X ft)
Production						
Process	4	36	1.0	70		
Storage	3	24	0.17	80		
Fugitive						400 X 800
Acetic acid						
Process	4	30	1.2	75	190	
Storage	4	24	0.17	80		
Fugitive						300 X 300
Peracetic acid						
Process	1	30	1.0	80	110	
Storage	2	24	0.17	80		
Fugitive						300 X 300
Pentaerythirtol						
Process	3	140	1.5	140	175	
Storage	2	20	0.33	70		
Fugitive						100 X 200
Pyridenes						
Process	1	30	0.5	100	10	
Storage	2	16	0.17	80		
Fugitive						100 X 200

Table 1-10. (Continued)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Distribution Area (ft X ft)
Glyoxal						
Process	2	20	0.08	70	5	
Storage	2	16	0.17	70		
Fugitive						100 X 100
1,3-Butylene glycol						
Process	2	20	0.08	65	44	
Fugitive						100 X 100

Note: building cross-section for production and end-uses - 50 m^2.

B. USES

Emission estimates for the end-users of acetaldehyde in 1978 are summarized in Table 1-11. They are based on the emission factors tabulated in Table 12.

Acetaldehyde emissions from acetic acid production were estimated to have been 1,867,130 lb. Other associated emissions would include acetic acid and ethyl acetate.

Acetaldehyde emissions from peracetic acid production were estimated to have been 450,000 lb. Other associated emissions would include ethyl acetate and peracetic acid.

Pentaerythritol production contributed an estimated 688,000 lb of acetaldehyde. Other associated emissions would include formaldehyde, ammonia, and pentaerythritol.

Pyridenes manufacture release an estimated 300,000 lb of acetaldehyde. Other emission components include picoline, formaldehyde, and pyridene.

Glyoxal production contributed an estimated 180,000 lb of acetaldehyde. Other associated emissions besides blyoxal are unknown.

1,3-Butylene glycol manufacture contributed 27,000 lb of acetaldehyde emissions. Other associated emissions include ethanol, dioxane, and 1,3-butylene glycol.

Miscellaneous uses of acetaldehyde were estimated to have contributed 153,900 lb. These uses are too diverse and numerous to specify or location. Emissions were estimated by taking a weighted average of all the other acetaldehyde end-uses and multiplying by the 30 million lb used.

The total nationwide emissions of acetaldehyde in 1978 were estimated to have been 3,921,260 lb. A tabulation of the losses is shown in Table 1-13.

Table 1-11. Acetaldehyde Emissions from End-Users

Company	Location	End-Use	Emissions (lb/yr) Process	Storage	Fugitive	Total Emissions[a] (lb/yr)	(g/sec)[b]
Celanese	Bay City, TX	Acetic acid	180,880	22,440	10,200	213,520	3.07
	Clear Lake, TX	Acetic acid	1,133,660	0	55,950	1,189,610	17.13
Eastman	Kingsport, TN	Acetic acid	392,239	49,743	22,018	464,000	6.68
FMC	Buffalo, NY	Peracetic acid	135,000	7,330	7,670	150,000	2.16
High Point	High Point, NC	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Union Carbide	Taft, LA	Peracetic acid	135,000	7,330	7,670	150,000	2.16
Celanese	Bishop, TX	Pentaerythritol	241,230	29,040	13,530	283,800	4.09
Hercules	Louisiana, MO	Pentaerythritol	153,510	18,480	8,610	180,600	2.60
IMC	Seiple, PA	Pentaerythritol	80,410	9,680	4,510	94,600	1.36
Perstorp	Toledo, OH	Pentaerythritol	109,650	13,200	6,150	129,000	1.86
Nepara	Harriman, NY	Pyridenes	108,460	10,880	8,160	127,500	1.84
Reilly	Indianapolis, IN	Pyridenes	146,740	14,720	11,040	172,500	2.48
American Cyanamide	Charlotte, NC	Glyoxal	81,000	4,400	4,600	90,000	1.30
Union Carbide	Taft, LA	Glyoxal	81,000	4,400	4,600	90,000	1.30
Celanese	Bishop, TX	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Eastman	Rochester, NY	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Mallinckrodt	Lodi, NJ	1,3-Butylene glycol	8,135	0	865	9,000	0.13
Total			3,138,184	198,973	174,973	3,512,130	

[a] Derived from the emission factors shown in Table 12.

[b] Based on 8760 hr/yr operation.

Table 1-12. Acetaldehyde End-Use Emission Factors

End-Use	Process	Derivation[a]	Storage	Derivation	Fugitive	Derivation	Total
Acetic acid - Celanese	0.00266	B	0.00033	B	0.00061	B	0.00314[b]
Acetic acid - Eastman	0.00481	B	0.00015	B	0.00027	B	0.00569[c]
Peracetic acid	0.00405	B	0.00022	B	0.00023	B	0.00450[d]
Pentaerythritol	0.00731	C	0.00088	C	0.00041	C	0.00860[e]
Pyridenes	0.00638	C	0.00004	C	0.00048	C	0.00750[e]
Glyoxal	0.00405	D	0.00022	D	0.00023	D	0.00450[f]
1,3-Butylene glycol	0.00122	B	0	B	0.00013	B	0.00013[g]

[a] A - Basis: site visit data
B - Basis: state emission files
C - Basis: published literature
D - Basis: Hydroscience estimate

[b] See refs. 7 and 8.

[c] See ref. 10.

[d] See ref. 12.

[e] See ref. 13.

[f] Hydroscience estimate.

[g] See ref. 14.

Table 1-13. 1978 Acetaldehyde Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Production	271,730
Acetic acid	1,867,130
Peracetic acid	450,000
Pentaerythritol	688,000
Pyridenes	300,000
Glyoxal	180,000
1,3-Butylene glycol	27,000
Miscellaneous*	137,400
Total	3,921,260

*Based on a weighted average of emission factors for other user categories. Factor: 0.00458 lb lost/lb used.

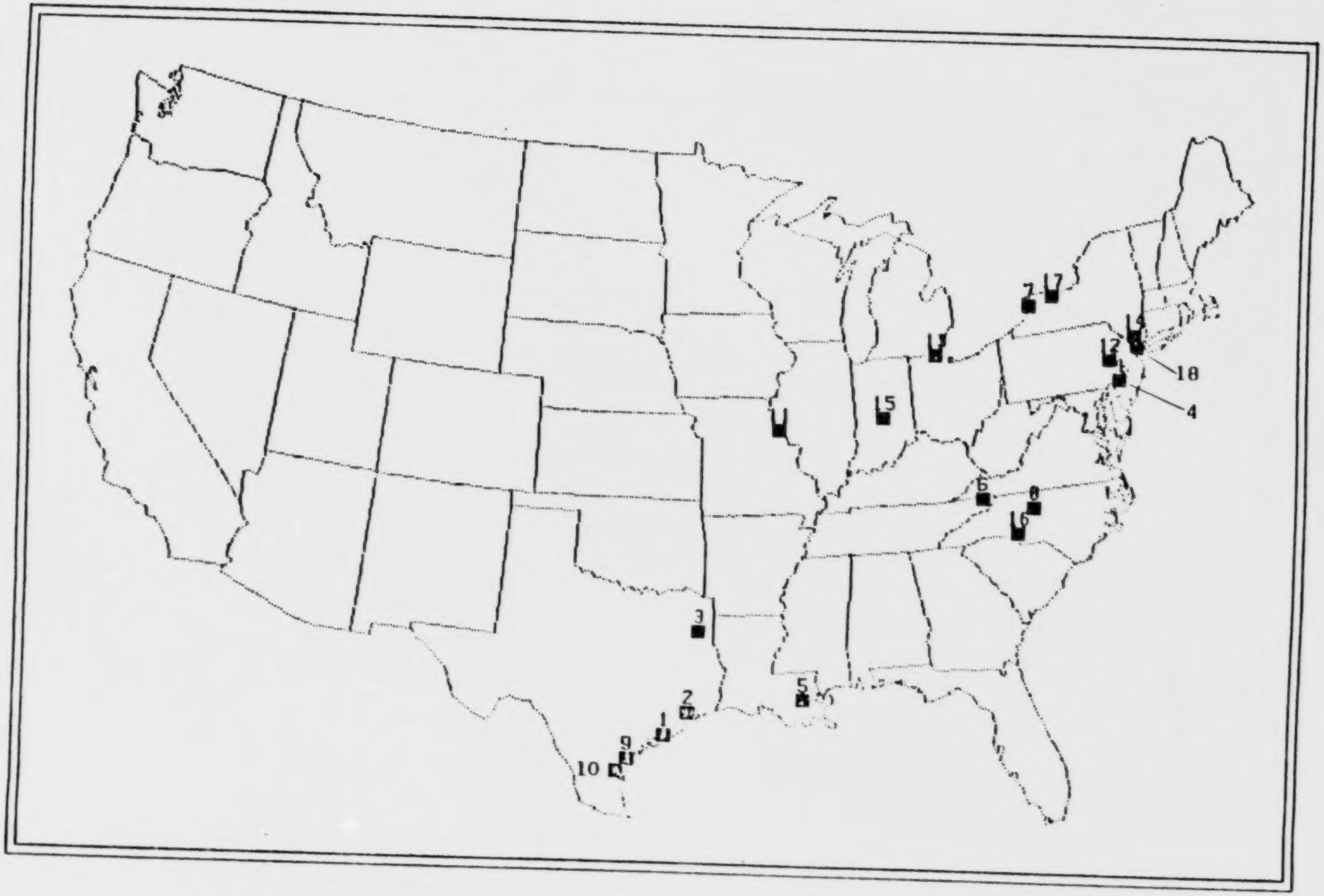

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FIGURE 1-1. SPECIFIC POINT SOURCES OF ACETALDEHYDE EMISSIONS

Table 1-14. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACETALDEHYDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	CELANESE	BAY CITY, TX	28 51 45	96 01 00	12923	1	1	.669711	.085141	.038177
							2	2.604642	.323186	.146880
2	CELANESE	CLEAR LAKE, TX	29 37 17	95 03 51	12906	1	1	1.533042	0.	.076294
							2	16.305808	0.	.804731
3	EASTMAN KODAK	LONGVIEW, TX	32 25 55	94 41 06	13972	2	1	1.116311	.142028	.063642
4	PUBLICKER	PHILADELPHIA, PA	39 53 30	75 12 18	13739	2	1	.144470	.018360	.008213
5.	SHELL	NORCO, LA	30 00 11	90 23 42	12958	2	1	.013064	.001617	.000719
6.	EASTMAN KODAK	KINGSPORT, TN	36 31 41	82 12 22	13877	3	2	1.410451	.178875	.316686
7.	FMC	BUFFALO, NY	42 59 10	78 50 30	14747	4	3	1.944000	.105530	.110445
8	HIGHPOINT	HIGH POINT, NC	35 59 10	80 00 37	93807	4	3	1.944000	.105530	.110445
9	UNION CARBIDE	TAFT, LA	27 58 00	97 27 00	13970	5	3	1.944000	.105530	.110445
10	CELANESE	BISHOP, TX	27 34 06	97 49 27	12925	6	6	1.166413	.063356	.066242
							4	2.089992	.377473	.117199
							7	.070523	0.	.007357
11	HERCULES	LOUISIANA, MO	39 26 24	91 03 37	93989	7	4	2.210521	.266109	.123985
12	IMC	SEIPLE, PA	40 38 21	75 31 38	14737	7	4	1.157915	.139396	.064942
13	PERSTORP	TOLEDO, OH	41 43 10	83 31 28	94830	7	4	1.578957	.190068	.088565
14	NEPARA	HARRIMAN, NY	41 16 40	74 08 24	14757	8	5	1.561834	.155505	.117516
15	REILLY TAR	INDIANAPOLIS, IN	39 42 00	86 14 00	93819	8	5	2.113045	.211948	.158961
16	AMER CYANAMID	CHARLOTTE, NC	35 12 16	80 50 32	13881	9	6	1.165049	.063293	.066178
17	EASTMAN KODAK	ROCHESTER, NY	43 12 01	77 37 58	14717	10	7	.117136	0.	.012462
18	MALLINCKRODT	LODI, NJ	40 52 56	74 05 46	94741	10	7	.117136	0.	.012462

TABLE 1-14 (Concluded)

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* Plant Types:

Type 1: Plant produces acetaldehyde and acetic acid

Type 2: Plant produces acetaldehyde

Type 3: Plant produces acetic acid

Type 4: Plant procudes peracetic acid

Type 5: Plant produces peracetic acid and glyoxal

Type 6: Plant produces pentaerythirtol and 1, 3-butylene glycol

Type 7: Plant produces pentaerythirtol

Type 8: Plant produces pyridenes

Type 9: Plant produces glyoxal

Type 10: Plant produces 1, 3-butylene glycol

† Source Types:

Type 1: Acetaldehyde production

Type 2: Acetic acid production

Type 3: Peracetic acid production

Type 4: Pentaerythirtol production

Type 5: Pyridenes production

Type 6: Glyoxal production

Type 7: 1, 3-butylene glycol

TABLE 1-15. EMISSIONS PARAMETERS FOR SPECIFIC POINT SOURCES OF ACETALDEHYDE

Source Type	Emissions Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
Acetaldehyde production	Process	10.8	50	0.3	--	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Acetic acid production	Process	9.0	50	0.36	57	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Peracetic acid production	Process	9.0	50	0.3	33	--
	Storage	7.2	50	0.05	--	--
	Fugitive	0	50	--	--	--
Pentaerythirtol production	Process	42	50	0.45	52	333
	Storage	4.8	50	0.10	--	--
	Fugitive	0	50	--	--	--
Pyridenes production	Process	9	50	0.15	3	311
	Storage	4.8	50	0.05	--	--
	Fugitive	0	50	--	--	--
Glyoxal production	Process	6	50	0.02	1.5	--
	Storage	4.8	50	0.05	--	--
	Fugitive	0	50	--	--	--

TABLE 1-15 (Concluded)

Source Type	Emission Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
1,3-Butylene glycol production	Process	6	50	0.02	13	--
	Fugitive	0	50	--	--	--

TABLE 1-16. EXPOSURE AND DOSAGE OF ACETALDEHYDE FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
250	2	499
100	14	2,310
50	58	5,040
25	459	18,300
10	2,517	48,500
5	5,663	71,200
2.5	14,670	103,000
1	64,410	177,000
0.5	167,890	247,000
0.25	441,702	342,000
0.1	933,239	419,000
0.05	1,627,955	469,000
0.025	2,773,705	509,000
0.01	4,493,446	538,000
0.005	5,478,435	545,000
0.0025	7,119,999	551,000
0.001	11,549,762	558,000
3.2×10^{-5}*	12,323,453	559,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 1-17. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF ACETALDEHYDE

Parameter	Value
Daytime decay rate (K_d)	7.3×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	1.98 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 1-18. ACETALDEHYDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (persons)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.010000	446,952	4,759.0	0.	100.0	0.	100.0	0.	0.
.005000	505,140	5,363.7	0.	100.0	0.	100.0	0.	0.
.002500	9,149,730	37,317.9	0.	100.0	0.	100.0	0.	0.
.001000	35,088,457	75,128.7	0.	100.0	0.	100.0	0.	0.
.000500	89,470,782	110,094.3	0.	100.0	0.	97.2	1.2	1.6
.000250	135,836,014	127,481.4	0.	100.0	0.	94.0	2.6	3.4
0	158,679,135	131,504.0	0.	100.0	0.	92.4	2.8	4.8

TABLE 1-19. EXPOSURE AND DOSAGE SUMMARY OF ACETALDEHYDE

	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
Concentration Level (ug/m^3)	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
250	2	0	0	2	499	0	0	499
100	14	0	0	14	2,310	0	0	2,310
50	58	0	0	58	5,040	0	0	5,040
25	459	0	0	459	18,300	0	0	18,300
10	2,517	0	0	2,517	48,500	0	0	48,500
5.	5,663	0	0	5,663	71,200	0	0	71,200
2.5	14,670	0	0	14,670	103,000	0	0	103,000
1	64,410	0	0	64,410	177,000	0	0	177,000
0.5	167,890	0	0	167,890	247,000	0	0	247,000
0.25	441,702	0	0	441,702	342,000	0	0	342,000
0.1	933,239	0	0	933,239	419,000	0	0	419,000
0.05	1,627,955	0	0	1,627,955	469,000	0	0	469,000
0.025	2,773,705	0	0	2,773,705	509,000	0	0	509,000
0.01	4,493,446	0	446,952	4,940.398	538,000	0	4,760	542,760
0.005	5,478,435	0	505,140	5,983,575	545,000	0	5,260	550,260
0.0025	7,119,999	0	9,149,730	16,269,729	551,000	0	37,300	588,300
0.001	11,549,762	0	35,008,457	46,558,219	558,000	0	75,100	633,100
0.0005	--	0	89,470,782	--	--	0	110,000	--
0.00025	--	0	135,836,014	--	--	0	127,000	--
0	12,323,453	0	158,679,135	158,679,135	559,000	0	132,000	691,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-2 ----- Acrolein

ACROLEIN CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 107-02-8

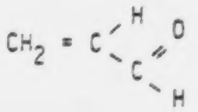
Synonyms: 2-Propenal; Acrylic Aldehyde; Allyl Aldehyde;
Acrylaldehyde; Acraldehyde

Chemical Formula

Molecular Weight: 56.06

Molecular Formula: C_3H_4O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - flammable, pungent odor

Boiling Point: 52.5°C

Melting Point: -86.95°C

Density: 0.8410 at 20°C/4°C

Vapor Pressure: 288.2 mm at 25°C

Vapor Density: 1.94

Solubility: very soluble, (400 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: Formaldehyde

Reactivity Toward $OH\cdot$: 1/2 Propylene

Reactivity Toward O_3: 1/2 Propylene

Reactivity Toward Photolysis: ≈ 5 x Formaldehyde

Major Atmospheric Precursors: N/A

Formation Reactivity: N/A

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A. ACROLEIN

All acrolein is currently produced in the United States by the direct oxidation of propylene.[1] The specific processes vary significantly, depending primarily on the by-product distribution desired and on the end-use requirements.[3,4]

Acrolein is currently produced by four companies at four locations in the United States.[1] The plant locations and the 1978 capacity and estimated production level for each plant are shown in Table 2-1. An estimated 350 million lb of arcrolein was produced in 1978.[5]

The largest end-use of acrolein is as an unisolated intermediate in the production of acrylic acid and its derivatives.[1] This end-use consumed an estimated 87% of production in 1978 amounting to 308 million lb.[5]

The end-uses of refined, or isolated, acrolein are small compared to its use as an unisolated intermediate in acrylic acid production. Synthetic glycerin consumed an estimated 24 million lb (7% of total acrolein production) in 1978.[5] Refined acrolein is also used in the manufacture of methionine and methionine hydroxy analogue (poultry feed supplements) which consumes 20 million lb. Miscellaneous applications consume the remaining 2 $\bar{M}$ lb and include 1,2,6-hexanetriol (a humectant used in flexible polyurethane foam manufacture), glutaraldehyde (used in leather tanning), and others.[1] Total consumption of acrolein in chemical intermediate applications is estimated to have been 22 million lb (6%) in 1978. End-uses are summarized in Table 2-2.[5]

Table 2-1. Production of Allyl Chloride, Epichlorohydrin, and Acrolein[a]

		1978 Estimated Production[b] (M lb)			1978 Estimated Capacity (M lb)			
Source	Location	Allyl Chloride	Epichlorohydrin	Acrolein	Allyl Chloride	Epichlorohydrin	Acrolein	Geographic Coordinates Latitude/Longitude
Dow Chemical Co.	Freeport, TX	176	166		265	250		28 59 30/95 23 35
Shell Chemical Co.	Deer Park, TX	77	73		117	110		29 42 55/95 07 34
Shell Chemical Co.	Norco, LA	77	73	24[c]	117	110	55[c]	30 00 11/90 23 42
Union Carbide Corp.	Taft, La			22[c]			60[c]	29 58 00/90 27 00
Celanese Corp.	Clear Lake, TX			89[d]			167[d]	29 37 17/95 03 51
Rohm and Haas Co.	Deer Park, TX			146[d]			273[d]	29 43 30/95 06 15
Union Carbide Corp.	Taft, LA			73[d]			137[d]	29 58 00/90 27 00
Total		330	312	354	499	470	692	

---

[a] See refs 1 and 2.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

[c] Isolated acrolein.

[d] Acrolein produced as an unisolated intermediate in the propylene oxidation process for acrylic acid and derivitives.

Table 2-2. 1978 Acrolein Consumption by End-Use[a]

End-Use	Usage (%)	End-Use Consumption ($\bar{M}$ lb)
Acrylic acid and esters[b]	87	308
Glycerin	7	24
Methionine and methionine hydroxy analogue	6	20
Miscellaneous[c]	>1	2
Total	100	354

[a] See refs. 1 and 2.

[b] Acrolein produced as an unisolated intermediate in the propylene oxidation process used to produce acrylic acid and esters.

[c] Includes glutaraldehyde, 1,2,6-hexane triol and others.

Estimated production losses are shown in Table 2-3 for each of the four producing locations. Total emissions of acrolein from production faclities are estimated to have been 70,835 lb. In the production of acrylic acid and derivatives (three locations) acrolein occurs only as an unisolated intermediate. Refined acrolein is produced at two locations. (One plant produces both acrylic acid and refined acrolein.) The emission sources and resulting emissions are significantly different for the two types of processes.

The predominant source of acrolein emissions from plants producing acrylic acid is the off-gas from the quench-absorber.[4] Other associated emission components include propane, propylene, acrylic acid, ethyl acrylate, acetone, and acetic acid. Emissions from this source are normally controlled by thermal oxidation.[4] With acrolein occurring only as an unisolated intermediate, storage emissions are negligible.[6,7] Fugitive emissions are those which result from plant equipment leaks.

The predominant sources of acrolein emissions from plants producing refined acrolein are the acrolein absorber vent (Union Carbide Process) and the condenser vents from the distillation columns. Other associated emission components include propane, propylene, and acetaldehyde.[3] With the use of pressurized tanks for storage the emissions of acrolein from storage sources are negligible.

Vent stack data for acrolein are shown in Table 2-4. Data for plants producing refined acrolein are also given in Table 2-4. Both types of production facilities are usually "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

Uses

The acrolein produced by acrylic acid manufacturers (308 million lb in 1978), which accounts for 87% of acrolein production, occurs as an unisolated intermediate. End-use emissions are included in production emissions. Similarly, the emissions of acrolein from the production of glycerin (7% of total acrolein consumption) are included in the production emissions since the glycerin is produced in the same plant.

Table 2-3. 1978 Acrolein Production Emissions

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions (lb/yr)	Total Emissions (g/sec)[a]
Shell	Norco, LA	26,400	0	2,640	29,040[b]	0.418
Union Carbide	Taft, LA	24,200	0	2,420	26,620[b]	0.383
Celanese	Clear Lake, TX	463	0	37	500[d]	0.007
Rohm and Haas	Deer Park, TX	9,050	0	730	9,780[c]	0.141
Union Carbide	Taft, LA	4,530	0	365	4,895[c]	0.071
Total		64,643	0	6,192	70,835	

[a] Based on 8760 hr/yr operation.

[b] Isolated acrolein emission factor (lb lost per lb produced). See ref. 3.

Process	0.00110	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.00011	A - Derived from site visit data
Total	0.00121	

[c] Unisolated acrolein emission factor (lb lost per lb acrolein produced). See ref. 4.

Process	0.000062	A - Derived from site visit data
Storage	0	A - Derived from site visit data
Fugitive	0.000005	A - Derived from site visit data
Total	0.000067	

[d] See ref. 11

Table 2-4. Acrolein Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Production[a,b,c] (acrylic acid mfgs)					
Process	1	50	2.7	70	50
Production[b,c] (refined acrolein)					
Process	1	120	0.3	70	72
End-use (Methionine)[b,d]					
Process	1	40	0.6	70	5

[a] Individual process vents are collected and fed to a single thermal oxidizer.

[b] Storage emissions are negligible.

[c] Building cross-section 10 m^2.

[d] Building cross-section 100 m^2.

Emissions resulting from the use of acrolein in the production of methionine and its derivatives, and in miscellaneous uses, were estimated by using the refined (isolated) acrolein production emission factor. Specific source locations for methionine manufacturers are shown in Table 2-5. Acrolein usage was distributed evenly over all four sites since capacities were not known. Specific locations for miscellaneous uses could not be identified.

Total nationwide emissions of acrolein in 1978 from all sources are estimated to have been 91,405 lb. A tabulation of the losses is shown in Table 2-6.

Table 2-5. 1978 Emissions of Acrolein from Methionine Production[a]

Company	Location	1978 Estimate Acrolein Used ($\bar{M}$ lbs)	Process Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[b,c] (lb/yr)	(g/sec)[d]	Geographic Coordinates Latitude/Longitude
Degussa	Theodore, AL	5.0	5,500	550	6,050	0.087	30 33 06/88 10 35
NAPP	Lodi, NJ	5.0	5,500	550	6,050	0.087	40 52 30/74 06 14
Dupont	Beaumont, TX	5.0	5,500	550	6,050	0.087	30 00 51/94 01 40
Monsanto	Nitro, WV	5.0	0	0	0[f]	0.0	38 24 26/81 51 26
Total		20.0	16,500	1,650[e]	18,150		

[a] See ref. 1.

[b] Based on isolated acrolein production emission factor.

[c] Storage emissions negilible.

[d] Based on 8760 hr/yr operation.

[e] Fugitive losses are distributed over a 100 ft X 100 ft area.

[f] Monsanto claims no emissions losses due to incineration of acrolein wastes.

Table 2-6. 1978 Estimated Acrolein Nationwide Emission Losses

Source	Estimated National Emissions (lb/yr)
Production	
Acrylic acid intermediate	15,175
Refined acrolein and glycerin	55,660
Chemical intermediate*	
Methionine	18,150
Miscellaneous	2,420
Total	91,405

*Based on emission factor of 0.00121 determined for isolated acrolein production.

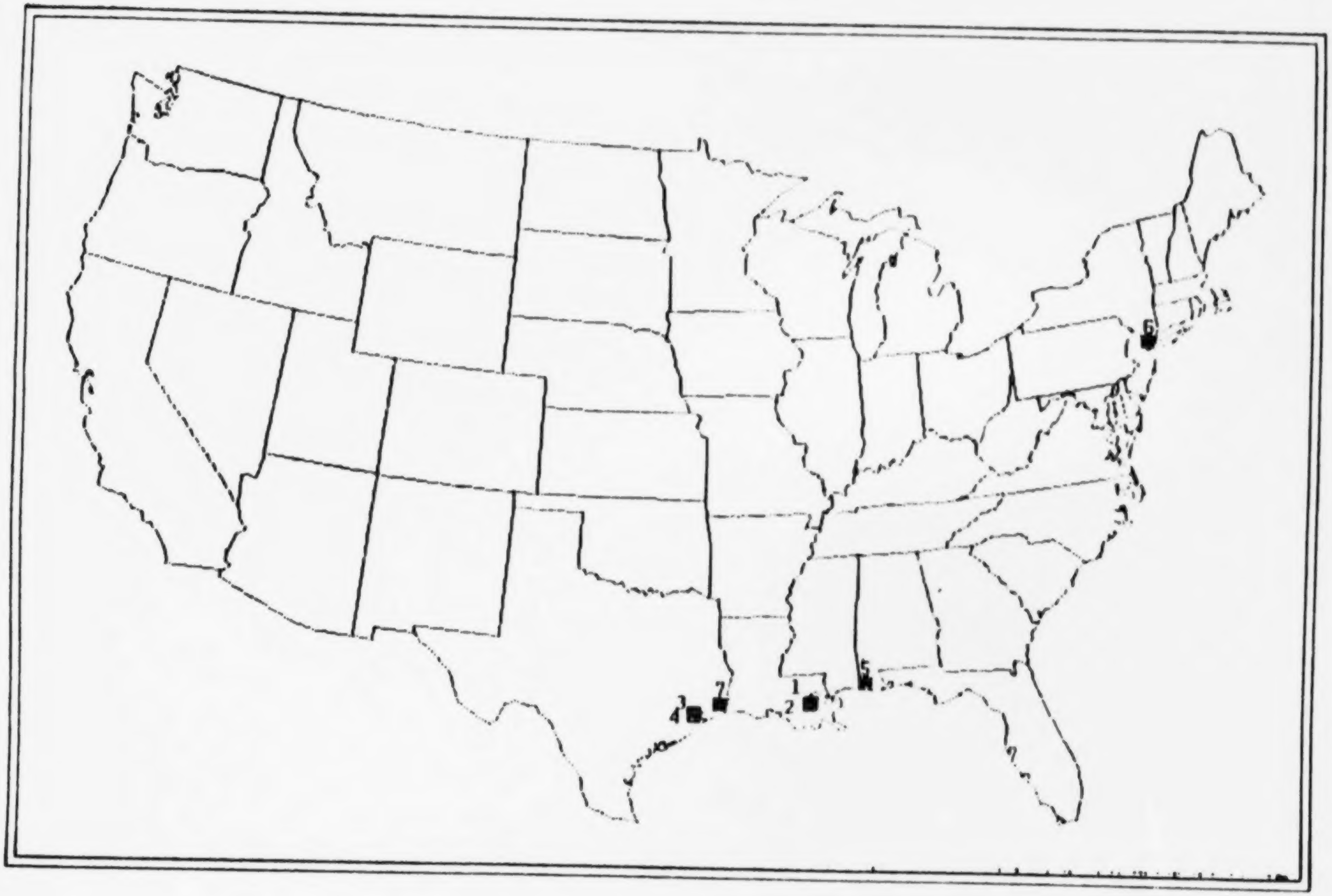

FIGURE 2-1. SPECIFIC POINT SOURCES OF ACROLEIN EMISSIONS

Table 2-7. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ACROLEIN

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	SHELL	NORCO, LA	30 00 11	090 23 42	12958	1	1	.380169	0.	.038020
2	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	2	1	.348491	0.	.034849
							2	.065227	0.	.005264
3	CELANESE	CLEAR LAKE, TX	29 37 17	095 03 51	12906	3	2	.006659	0.	.000539
4	ROHMAND HASS	DEER PARK, TX	29 43 30	095 06 30	12906	3	2	.130327	0.	.010528
5	DEGUSSA	THEODOR. AL	30 33 06	088 10 35	03855	4	3	.079211	0.	.007927
6	NAPP	LODI, NJ	40 52 30	074 06 14	94741	4	3	.050387	0.	.007927
7	DUPONT	BEAUMONT, TX	30 00 51	094 01 40	12917	4	3	.079211	0.	.007927

---

* Plant Types:

Type 1: Plant produces refined acrolein

Type 2: Plant produces refined acrolein and acrylic acid

Type 3: Plant produces acrylic acid and acrolein is the intermediate

Type 4: Plant produces methionine

+ Source Types:

Type 1: Refined acrolein production

Type 2: Acrylic acid production

Type 3: Methionine production

Table 2-8. EXPOSURE AND DOSAGE OF ACROLEIN RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
1	169	207
0.5	1,590	1,150
0.25	4,064	2,040
0.1	18,180	4,140
0.05	39,655	5,540
0.025	78,077	6,810
0.01	232,250	9,200
0.005	488,918	10,900
0.0025	1,022,985	12,800
0.001	4,047,571	17,100
0.0005	5,872,726	18,600
1.52×10^{-5}*	6,497,934	18,800

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 2-9. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF ACROLEIN

Parameter	Value
Daytime decay rate (K_d)	1.6×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.0348 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 2-10. ACROLEIN EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.000100	585140	91.0	0.	100.0	0.	100.0	0.	0.
.000050	9149730	589.8	0.	100.0	0.	100.0	0.	0.
.000025	20443737	925.3	0.	100.0	0.	100.0	0.	0.
.000010	55204345	1443.0	0.	100.0	0.	97.4	.9	1.7
.000005	127350709	1987.4	0.	100.0	0.	94.2	2.6	3.2
0.	150679135	2093.0	0.	100.0	0.	91.8	3.0	5.3

TABLE 2-11. EXPOSURE AND DOSAGE SUMMARY OF ACROLEIN

Concentration Level (ug/m^3)	Population Exposed (persons) Specific Point Source	General Point Source	Area Source	U.S. Total	Dosage [(ug/m^3) - persons] Specific Point Source	General Point Source	Area Source	U.S. Total
1	169	0	0	169	207	0	0	207
0.5	1,590	0	0	1,590	1,150	0	0	1,150
0.25	4,064	0	0	4,064	2,040	0	0	2,040
0.1	18,180	0	0	18,180	4,140	0	0	4,140
0.05	39,655	0	0	39,655	5,540	0	0	5,540
0.025	78,077	0	0	78,077	6,810	0	0	6,810
0.01	232,250	0	0	232,250	9,200	0	0	9,200
0.005	488,918	0	0	488,918	10,900	0	0	10,900
0.0025	1,022,985	0	0	1,022,985	12,800	0	0	12,800
0.001	4,047,571	0	0	4,047,571	17,100	0	0	17,100
0.0005	5,872,726	0	0	5,872,726	18,600	0	0	18,600
0.0001	---	0	505,140		---	0	91	---
0.00005	---	0	9,149,730		---	0	590	---
0.000025	---	0	20,443,737		---	0	925	---
0.00001	---	0	55,204,345		---	0	1,443	---
0.000005	---	0	127,350,709		---	0	1,987	---
0	6,497,934	0	158,679,135	158,679,135	18,800	0	2,094	20,894

Note: The use of -- as an entry indicates that the incremental E/D is not significant relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. S. L. Soder and K. Ring, "Propylene," pp. 300.5405E-300.5405L in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (August 1978).

2. J. L. Blackford, "Epichlorohydrin," pp. 642.3021A-642.3022M in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1978).

3. C. A. Peterson, Jr., Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufcturing Industry---Product Report on Glycerin and Its Intermediates (Allyl Chloride, Epichloronydrin, Acrolein, and Allyl Alcohol (on file at EPA, ESED, Research Triangle Park, NC) (March 1979).

4. J. W. Blackburn, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry---Acrylic Acid and Esters Product Report (on file at EPA, ESED, Research Triangle Park, NC) (July 1978).

5. CEH Manual of Current Indicators---Supplementary Data, p. 84 in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (April 1979).

6. D. B. Dimick, Dow Chemical, Freeport, TX, Texas Air Control Board Emissions Inventory Questionnaire for 1975, Epichlorohydrin, Glycerin No. 1.

7. Dow Chemical Co., Freeport, TX, Texas Air Control Board Emission Inventory Questionaire for 1975, Allyl Chloride, Glycerin II.

8. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Glycerin and Associated Products.

9. Shell Chemical Co., Norco, LA, Louisiana Air Control Commission Emission Inventory Questionnaire (January 31, 1977).

10. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Resins Process.

11. Celanese Chemical Company, Inc. (R. H. Maurer) Personal communication in response to first draft of this document (July 1981).

APPENDIX A-3 ----- Allyl Chloride

ALLYL CHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 107-05-1

Synonyms: 3-Chloroprene; AC; Chlorallylene; 3-Chloro-1-propene;
1-Chloro-2-propene; 3-Chloropropylene

Chemical Formula

Molecular Weight: 76.53

Molecular Formula: C_3H_5Cl

Molecular Structure: $CH_2 = CH - CH_2Cl$

Chemical and Physical Properties

Physical State at STP: Liquid, pungent odor

Boiling Point: 44.6°C

Melting Point: -134.5°C

Density: 0.938 at 20°C/4°C

Vapor Pressure: 359 mm at 25°C

Vapor Density: 2.64

Solubility: Soluble (33 g/1 of H_2O) at 20°

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: 2-Chloroacetaldehyde; Formaldehyde

Reactivity Toward OH·: 2 x Butane

Reactivity Toward O_3: 15% of propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

A. ALLYL CHLORIDE

All allyl chloride currently produced in the United States by the chlorination of propylene is consumed in the production of epichlorohydrin.[1,2] Allyl chloride is first reacted with hypochlorous acid to form dichlorohydrin; dichlorohydrin is then reacted with sodium hydroxide or calcium hydroxide to form crude epichlorohydrin.[2]

Crude epichlorohydrin can be used directly for the production of synthetic glycerin.[2] For other end-uses (primarily expoxy resins) the crude product is further refined by distillation.[2]

Allyl chloride and epichlorohydrin are both produced by two companies at three locations.[2] The plant locations and the 1978 capacities and estimated production levels for each plant are shown in Table 3-1.[1,2] The estimated quantities of allyl chloride and epichlorohydrin produced in 1978 were 330 million lb and 312 million lb respectively.[2]

The primary end-uses of epichlorohydrin are for the manufacture of epoxy resins and synthetic glycerin. An estimated 53% of epichlorohydrin production amounting to 165 million lb was consumed to produce epoxy resins and 25%, or 78 million lb, was consumed in the manufacture of synthetic glycerin.[1,2]

Most of the other applications of epichlorohydrin are relatively minor. Epichlorohydrin elastomers consumed an estimated 6 million lb (2%) in 1978. An estimated 47 million lb (15%) was used to produce a variety of products in relatively small volume including glycidol ethers, some types of modified epoxy resins, wet strength resins for the paper industry, water treatment resins, surfactants, and ion-exchange resins. Exports of epichlorohydrin are estimated to have been 16 million lb (5%) in 1978. End-uses are summarized in Table 15-2.[1,2] Specific source locations of the epoxy resin producers are shown in Table 15-3.[1,2]

EMISSIONS ESTIMATES

1. Production

Estimated production losses are shown in Table 3-2 for each of the three producing locations. Total emissions of allyl chloride and epichlorohydrin from production facilities are estimated to have been 1,112,100 lb and 146,640 lb respectively in 1978.[3] Process emissions originate primarily through the condenser vents

Table 3-1. Production of Allyl Chloride, Epichlorohydrin, and Acrolein[a]

		1978 Estimated Production[b] (M lb)			1978 Estimated Capacity (M lb)			
Source	Location	Allyl Chloride	Epichlorohydrin	Acrolein	Allyl Chloride	Eqichlorohydrin	Acrolein	Geographic Coordinates Latitude/Longitude
Dow Chemical Co.	Freeport, TX	176	166		265	250		28 59 30/95 23 35
Shell Chemical Co.	Deer Park, TX	77	73		117	110		29 42 55/95 07 34
Shell Chemical Co.	Norco, LA	77	73	24[c]	117	110	55[c]	30 00 11/90 23 42
Union Carbide Corp.	Taft, La			22[c]			60[c]	29 58 00/90 27 00
Celanese Corp.	Clear Lake, TX			89[d]			167[d]	29 37 17/95 03 51
Rohm and Haas Co.	Deer Park, TX			146[d]			273[d]	29 43 30/95 06 15
Union Carbide Corp.	Taft, LA			73[d]			137[d]	29 58 00/90 27 00
Total		330	312	354	499	470	692	

[a] See refs 1 and 2.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

[c] Isolated acrolein.

[d] Acrolein produced as an unisolated intermediate in the propylene oxidation process for acrylic acid and derivitives.

Table 3-2. 1978 Allyl Chloride and Epichlorohydrin Production Emissions

		Process Emissions		Storage Emissions		Fugitive Emissions		Total Emissions			
								Allyl Chloride[a]		Epichlorohydrin[b]	
Company	Location	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	Allyl Chloride (lb/yr)	Epichlorohydrin (lb/yr)	(lb/yr)	(g/sec)[c]	(lb/yr)	(g/sec)[c]
Dow	Freeport, TX	515,680	69,720	24,640	1,660	52,800	6,640	593,120	8.54	78,020	1.12
Shell	Deer Park, TX	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
	Norco, LA	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
Total		966,900	131,040	46,200	3,120	99,000	12,400	1,112,100		146,640	

[a] Based on allyl chloride emission factor (lb lost/lb produced). See refs. 7—9.

Process 0.00293 B - From state files
Storage 0.00014 B - From state files
Fugitive 0.00030 D - Engineering estimate
Total 0.00337

[b] Based on epichlorohydrin emission factor (lb lost/lb produced). See refs. 6, 8, and 9.

Process 0.00042 B - Fron state files
Storage 0.00001 B - From state files
Fugitive 0.00004 D - Engineering estimate
Total 0.00047

[c] Based on 8760 hr/yr operation.

from the distillation columns.[3] Other associated emissions include C_3 hydrocarbons and other C_3 chlorinated hydrocarbons.[3] Storage emissions, which represent total losses from storage tanks and loading and handling, are generally controlled by the use of pressurized tanks and/or refrigerated vent condensers and account for less than 5% of allyl chloride losses and less than 3% of epichlorohydrin losses.[6,7] Fugitive emissions are those which result from plant equipment leaks.

Vent stack data are shown in Table 3-3. Typically, there are four process vents that emit allyl chloride and three process vents that emit epichlorohydrin. Emissions from banks of storage tanks are normally collected and discharged from common vent stacks. Usually allyl chloride/epichlorohydrin production facilities are "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

2. Uses

For the purpose of this report, emissions resulting from the export of epichlorohydrin are assumed to be negligible.

Since the only significant end-use for allyl chloride is in the production of epichlorohydrin, allyl chloride end-use emissions are included in the allyl chloride/epichlorohydrin production emissions.

More than half (53%) of the epichlorohydrin produced is used in the production of epoxy resins. The current domestic producers of epoxy resins, plant locations, and estimated emissions of epichlorohydrin are given in Table 15-6. Vent parameter data relative to epichlorohydrin emissions from epoxy resin production are shown in Table 3-3.

Emissions of epichlorohydrin resulting from the production of glycerin, the next largest end-use of epichlorohydrin (25%), are included in the listed epichlorohydrin production emissions. (Glycerin and the required epichlorohydrin are produced at the same location.) Emissions resulting from the use of epichlorohydrin in the production of miscellaneous products were estimated by using the epoxy resin (epichlorohydrin use) emission factor. Specific source locations for miscellaneous chemical intermediate use could not be identified.

Total nationwide emissions of allyl chloride and epichlorohydrin in 1978 from all sources are estimated to have been 1.11 million lb and 0.479 million lb respectively. A tabulation of the losses is shown in Table 3-4.

Table 3-3. Allyl Chloride and Epichlorohydrin Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[a,b]					
Process vents					
Allyl chloride	2	85	0.6	80	Intermittent
	2	40	0.167	228	5.5
Epichlorohydrin	3	50	0.34	90	13.8
Storage vents					
Allyl chloride	2	15 - 20	0.6	86	
Epichlorohydrin	2	15 - 20	0.6	80	
Use[c,d]					
Epoxy resins, elastomers and misc. products					
Process					
Column vent	1	50	0.33	115	5.3
Recovery vents	3	135	0.83	110	10.0
Storage	7	20	0.17	80	

[a] Building cross-section 5 m^2.

[b] Fugitive emissions distributed over a 300 ft X 300 ft area.

[c] Building cross-section 100 m^2.

[d] Fugitive emissions distributed over a 100 ft X 200 ft area.

Table 3-4. 1978 Estimated Allyl Chloride and Epichlorohydrin Nationwide Emission Losses

Source	Estimated National Emissions	
	Allyl Chloride (M lb/yr)	Epichlorohydrin (M lb/yr)
Production (allyl chloride, epichlorohydrin, and glycerin)	1.11	0.147
Unmodified epoxy resins - use		0.251
Chemical intermediate - use		0.081
Export	0	0
Total	1.11	0.479

*Based on emission factor of 0.00152 lb lost per lb used derived for epoxy resin manufacture.

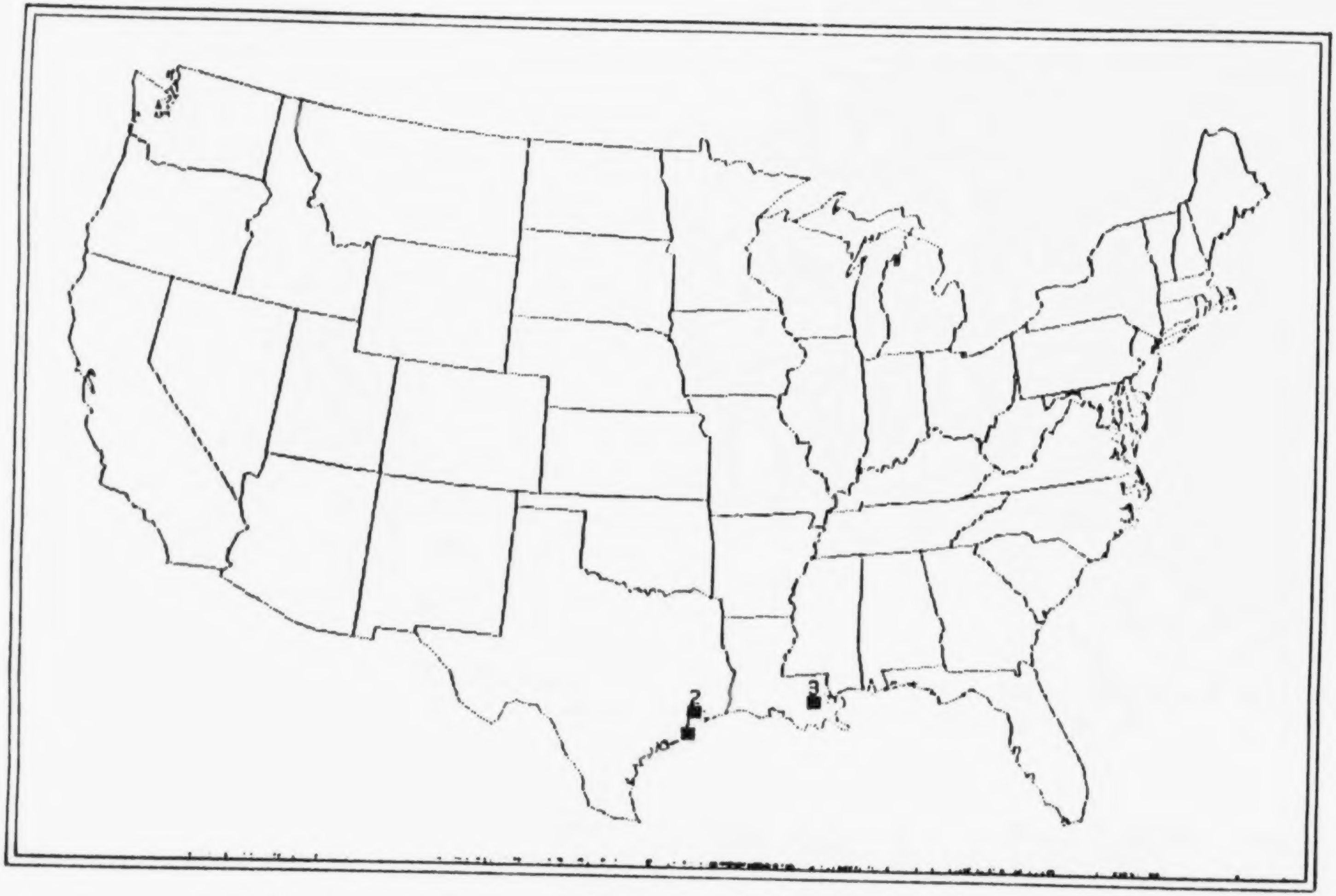

FIGURE 3-1. SPECIFIC POINT SOURCES OF ALLYL CHLORIDE EMISSIONS

TABLE 3-5. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ALLYL CHLORIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE* TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	I	I	7.425792	.354016	.760320
2	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	I	I	3.248784	.155232	.332640
3	SHELL	NORCO, LA	30 00 11	090 23 42	12958	I	I	3.248784	.155232	.332640

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* All allyl chloride currently produced in the United States is consumed in the production of epichlorohydrin. Therefore, the only emissions sources are the allyl chloride production facilities.

TABLE 3-6. EXPOSURE AND DOSAGE OF ALLYL CHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
25	19	576
10	127	2,210
5	376	3,960
2.5	1,812	8,610
1	10,178	20,900
0.5	26,109	31,800
0.25	63,281	45,300
0.1	170,957	62,600
0.05	300,767	71,500
0.025	549,875	80,000
0.01	913,265	86,500
0.0047*	940,280	86,700

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. S. L. Soder and K. Ring, "Propylene," pp. 300.5405E—300.5405L in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (August 1978).

2. J. L. Blackford, "Epichlorohydrin," pp. 642.3021A—642.3022M in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (May 1978).

3. C. A. Peterson, Jr., Hydroscience, Inc., *Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Glycerin and Its Intermediates (Allyl Chloride, Epichlorohydrin, Acrolein, and Allyl Alcohol* (on file at EPA, ESED, Research Triangle Park, NC)(March 1979).

4. J. W. Blackburn, Hydroscience, Inc., *Emisson Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Acrylic Acid and Esters Product Report* (on file at EPA, ESED, Research Triangle Park, NC) (July 1978).

5. CEH Manual of Current Indicators——Supplementary Data, p. 84 in *Chemical Economics Handbook*, Stanford Research Institute, Menlo Park, CA (April 1979).

6. D. B. Dimick, Dow Chemical, Freeport, TX, Texas Air Control Board Emissions Inventory Questionnaire for 1975, Epichlorohydrin, Glycerin No. 1.

7. Dow Chemical Co., Freeport, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Allyl Chloride, Glycerin II.

8. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Glycerin and Associated Products.

9. Shell Chemical Co., Norco, LA, Louisiana Air Control Commission Emission Inventory Questionnaire (January 31, 1977).

10. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Resins Process.

APPENDIX A-4 ----- Benzyl Chloride

BENZYL CHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 100-44-7

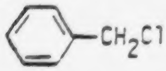
Synonyms: α-Tolylchloride; Chloromethylbenzene; α-Chlorotoluene

Chemical Formula

Molecular Weight: 126.5

Molecular Formula: C_7H_7Cl

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - very refractive, irritating odor

Boiling Point: 179°C at 760 mm

Melting Point: -39°C

Density: 1.1026 at 18°C/4°C

Vapor Pressure: 1.4 mm at 25°C

Vapor Density: 4.36

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 2 x Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Benzyl chloride ($C_6H_5CH_2Cl$) is currently produced in the United States by the direct chlorination of boiling toluene. In this process, boiling toluene is chlorinated in the absence of light until the proper weight increase is achieved. The reaction mixture is then agitated with mild alkali and distilled. Benzyl chloride and benzotrichloride are formed as by-products. Other processes for producing benzyl chloride which are not in use in the U.S. today include chlorination of toluene using sulfuryl chloride and the chloromethylation of benzene using formaldehyde and hydrogen chloride.

There are currently three producers of benzyl chloride at three locations in the United States. The site locations of the plants and the 1978 capacity and estimated production levels for each plant are shown in Table 4-1.[1] In 1978 an estimated 115 million lb of benzyl chloride was produced.

B. USES

The major use of benzyl chloride is for the production of butyl benzyl phthalate, a plasticizer used in the manufacture of polyvinyl chloride (PVC) for floor coverings. An estimated 75% (86.25 million lb) of benzyl chloride production was consumed for this end-use. Butyl benzyl phthalate is produced by reacting butyl alcohol, benzyl chloride, and phthalic anhydride in the presence of an acid catalyst. The site locations of the butyl benzyl phthalate producers are shown in Table 4-2.[2]

Quaternary ammonium compounds are the second largest outlet for benzyl chloride. They are formed by reacting benzyl chloride with dimethyl alkyl amines and are used primarily as germicides. Approximately 10% (11.5 million lb) was consumed for this end-use. Source locations of the major quaternary ammonium compound manufactures are shown in Table 4-3.[2]

Benzyl alcohol production consumed 7% of benzyl chloride production (8.0 million lb). Benzyl alcohol is made by the hydrolysis of benzyl chloride with an alkali. Benzyl alcohol is used primarily as a textile dye assistant. Source locations of benzyl alcohol producers are shown in Table 4-4.[3]

Table 4-1. Benzyl Chloride Producers[a]

Company	Location	1978 Capacity (10^6 lb/yr)	1978[b] Production (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Monsanto	Bridgeport, NJ	80	52.5	39 47 33/75 23 45
	Sauget, IL[c]	80	52.5	38 35 31/90 10 11
Stauffer	Edison, NJ	12	8.0	40 29 23/74 23 03
UOP, Inc.	East Rutherford, NJ	3	2.0	40 49 46/74 05 30
Total		175	115.0	

[a] See ref. 1.

[b] Based on ratio of production to capacity of 66% (see ref. 1).

[c] Monsanto reports that the Sauget, IL unit was shutdown in July 1982. Emissions calculations have been revised to omit this source.

Table 4-2. Butyl Benzyl Phthalate Producers[a]

Company	Location	1978 Butyl Benzyl Phathalate Capacity (10^6 lb/yr)	1976 Benzyl Chloride[b] Used (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Monsanto	Bridgeport, NJ	NA[c]	43.125	39 47 33/75 23 45
	Sauget, IL[d]	NA	43.125	38 35 31/90 10 11
Total			86.25	

[a] See ref. 2.

[b] Total benzyl chloride use of 86.25 million lb was distributed evenly over both sites since capacity data were not available.

[c] Not available.

[d] Monsanto reports that the Sauget, IL. unit was shutdown in July 1982. Emissions calculations have been revised to omit this source.

Table 4-3. Quaternary Ammonium Compounds Producers[a]

Company	Location	Quaternary Ammonium Compound Capacity (lb/yr)	Benzyl Chloride[b] Used (lb/yr)	Geographic Coordinates Latitude/Longitude
Akzona	McCook, IL	NA[c]	92,500	41 48 17/87 49 41
	Morris, IL	NA	92,500	41 24 24/88 18 10
Lonza	Mapleton, IL	NA	92,500	40 34 00/89 43 01
Hexcel	Lodi, NJ	NA	92,500	40 52 00/74 06 50
Witco	Houston, TX	NA	92,500	29 34 45/95 26 00
Ashland	Janesville, WI	NA	92,500	42 41 56/89 00 10
Gulf Oil	Jersey City, NJ	NA	92,500	40 43 02/74 06 14
Rohm & Haas	Philadelphia, PA	NA	92,500	39 54 50/75 11 30
Sterling	Cincinnati, OH	NA	92,500	39 05 15/84 33 09
National Starch	Salisbury, NC	NA	92,500	35 43 36/80 28 19
Total			9,250,000	

---

[a] See ref. 2.

[b] Total benzyl chloride usage distributed evenly over all 10 sites.

[c] Not available.

Table 4-4. Benzyl Alcohol Producers[a]

Company	Location	1978 Capacity Benzyl Alcohol (10^6 lb/yr)	1978[b] Benzyl Chloride Use (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Stauffer Chemical	Edison, NJ	5	2.7	40 29 23/74 23 07
UOP, Inc.	E. Rutherford, NJ	2	1.0	40 49 46/74 05 30
Velsicol	Chattanooga, TN	5	2.7	30 36 31/85 16 36
Orbis	Newark, NJ	1.5	0.8	40 41 16/74 12 17
Norda	Boonton, NJ	1.5	0.8	40 54 13/74 24 44
Total		15	8.0	

[a] See ref. 3.

[b] Based on 7% of benzyl chloride that is used to make benzyl alcohol (sse ref. 1).

$$\text{Benzyl alcohol used} = \frac{\text{BA capacity}}{15} \times 0.07\ (115 \times 10^6\ \text{lb/yr benzyl chloride produced}).$$

The remaining benzyl chloride production (8%) representing 9.25 million lb was used in a variety of small diverse chemical intermediate end-uses. Benzyl chloride end-uses are summarized in Table 4-5.[1]

II. EMISSION ESTIMATES

A. PRODUCTION

Benzyl chloride emissions from production sites are presented in Table 4-6. Total estimated emissions from these sites are 24,260 lb. Emission factors derived from state files[4,5] included both benzyl chloride production emissions and benzyl alcohol consumption emissions. They apply only to Stauffer at Edison, NJ and UOP at E. Rutherford, NJ. These factors are shown in Table 4-7. Emissions from the Monsanto facility were provided by Monsanto.[7] Process emissions originate primarily from scrubber vents and vacuum jets. Other associated emission components would include toluene, hydrochloric acid, and chlorine.

Storage emissions represent the losses from both working and final product storage as well as loading and handling losses. Fugitive emissions are those that are result from plant equipment leaks.

Vent parameter data are reported in Table 4-8 for both producers and end-users.

B. USES

Emission estimates for end-users of benzyl chloride are summarized along with production emissions in Table 4-6. They are based on the emission factors tabulated in Table 4-7, except where noted.

Benzyl chloride emissions from butyl benzene phthalate production are estimated to be 6,300 lb. Other associated emissions would include phthalic anhydride and butanol.

Benzyl chloride emissions from benzyl alcohol production are estimated to have been 2150 lb. However the emissions from benzyl alcohol manufactured at Stuaffer and UOP are already included in the benzyl chloride production emission losses.

Table 4-5. Benzyl Chloride End-Uses 1978*

Use	Usage (10^6 lb/yr)	Usage (%)
Butyl benzyl phthalate	86.25	75
Benzyl alcohol	8.0	7
Quaternary ammonium compounds	11.5	10
Miscellaneous	9.25	8
Total	115	100

*See ref. 1.

Table 4-6. Benzyl Chloride Emissions from Producers and Users

Company	Location	Source	Emissions (lb/yr)			Total Emissions[a]	
			Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Monsanto	Bridgeport, NJ	Production	14,070	1,217	2,614	17,900	0.257
Stauffer	Edison, NJ	Production	4,000	344	744	5,088	0.073
UOP	E. Rutherford, NJ	Production	1,000	86	186	1,272	0.018
Monsanto	Bridgeport, NJ	BBP	4,720	500	1,080	6,300	0.091
Velsicol	Chattanooga, TN	Benzyl alcohol	945	108	297	1,350	0.019
Orbis	Newark, NJ	Benzyl alcohol	280	32	88	400	0.006
Norda	Boonton, NJ	Benzyl alcohol	280	32	88	400	0.006
Akzona	McCook, IL	QAC	322	46	92	460	0.007
	Morris, IL	QAC	322	46	92	460	0.007
Lonza	Mapelton, IL	QAC	322	46	92	460	0.007
Hexcel	Lodi, NJ	QAC	322	46	92	460	0.007
Witco	Houston, TX	QAC	322	46	92	460	0.007
Ashland	Janesville, WI	QAC	322	46	92	460	0.007
Gulf Oil	Jersey City, NJ	QAC	322	46	92	460	0.007
Rohm & Haas	Philadelphia, PA	QAC	322	46	92	460	0.007
Sterling	Cincinnati, OH	QAC	322	46	92	460	0.007
National Starch	Salisbury, NC	QAC	322	46	92	460	0.007
Total			28,515	2,779	6,017	37,310	

[a] Based on emission factors shown in Table 7.

[b] Based on 8760 hr/yr operation.

[c] Based on Monsanto estimate.[7]

Table 4-7. Benzyl Chloride Emission Factors

Source	Emission Factor (lb lost/lb produced) (used)						
	Process	Derivation[a]	Storage	Derivation	Fugitive	Derivation	Total
Benzyl chloride production[b] (Stauffer/UOP)	0.000500	B	0.000043	B	0.000093	B	0.000636[d]
Benzyl alcohol	0.000350	C	0.000040	C	0.000110	C	0.000500[c]
Quaternary ammonium compounds	0.000280	D	0.000040	D	0.000080	D	0.000400[e]

---

[a] A - basis site visit data
B - basis state emission files
C - basis published data
D - basis Hydroscience estimate

[b] Emission factor represents benzyl chloride production and benzyl alcohol use loss.

[c] See ref. 6.

[d] See refs. 4 and 5.

[e] Hydroscience estimate.

Table 4-8. Benzyl Chloride Vent Paremeters

	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temp. (°F)	Velocity (ft/sec)	Distribution Area
Production						
Process	2	38	1.0	78	0.02	
Storage	6	24	0.17	70	0.02	
Fugitive						300 X 300
Butyl benzyl phthalate						
Process	1	36	0.6	90	5	
Storage	4	24	0.33	80		
Fugitive						200 X 300
Quaternary NH_3 compounds						
Process	1	20	0.33	75	14	
Storage	1	8	0.17	70		
Fugitive						100 X 100
Benzyl alcohol						
Process	2	36	0.33	80	10	
Storage	2	20	0.17	70		
Fugitive						300 X 300

Building cross-section for all sources - 50 m^2.

Quaternary ammonium compounds manufacture contributed an estimated 4600 lb of benzyl chloride emissions. Other emission components would likely be amines. Miscellaneous uses of benzyl chloride were estimated to have contributed 7493 lb of emissions. These uses are extremely small and too diverse and numerous to locate and specify individual emission quantities. Emissions were estimated by taking a weighted average of the other benzyl chloride end-uses and multiplying by the 9.25 million lb used.

The total nationwide emissions of benzyl chloride are estimated to be 44,803 lb. A tabulation of the losses is shown in Table 4-9.

Table 4-9. Benzyl Chloride Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Production	24,260
Butyl benzyl phthalate	6,300
Quaternary ammonium compounds	4,600
Benzyl alcohol	2,150[a]
Miscellaneous[b]	7,493
Total	44,803

[a] Emissions from the use of 3.7 million lb of benzyl chloride to produce benzyl alcohol are included in production.

[b] Based on a weighted average emission factor for all benzyl chloride uses of 0.000405 lb lost/lb used.

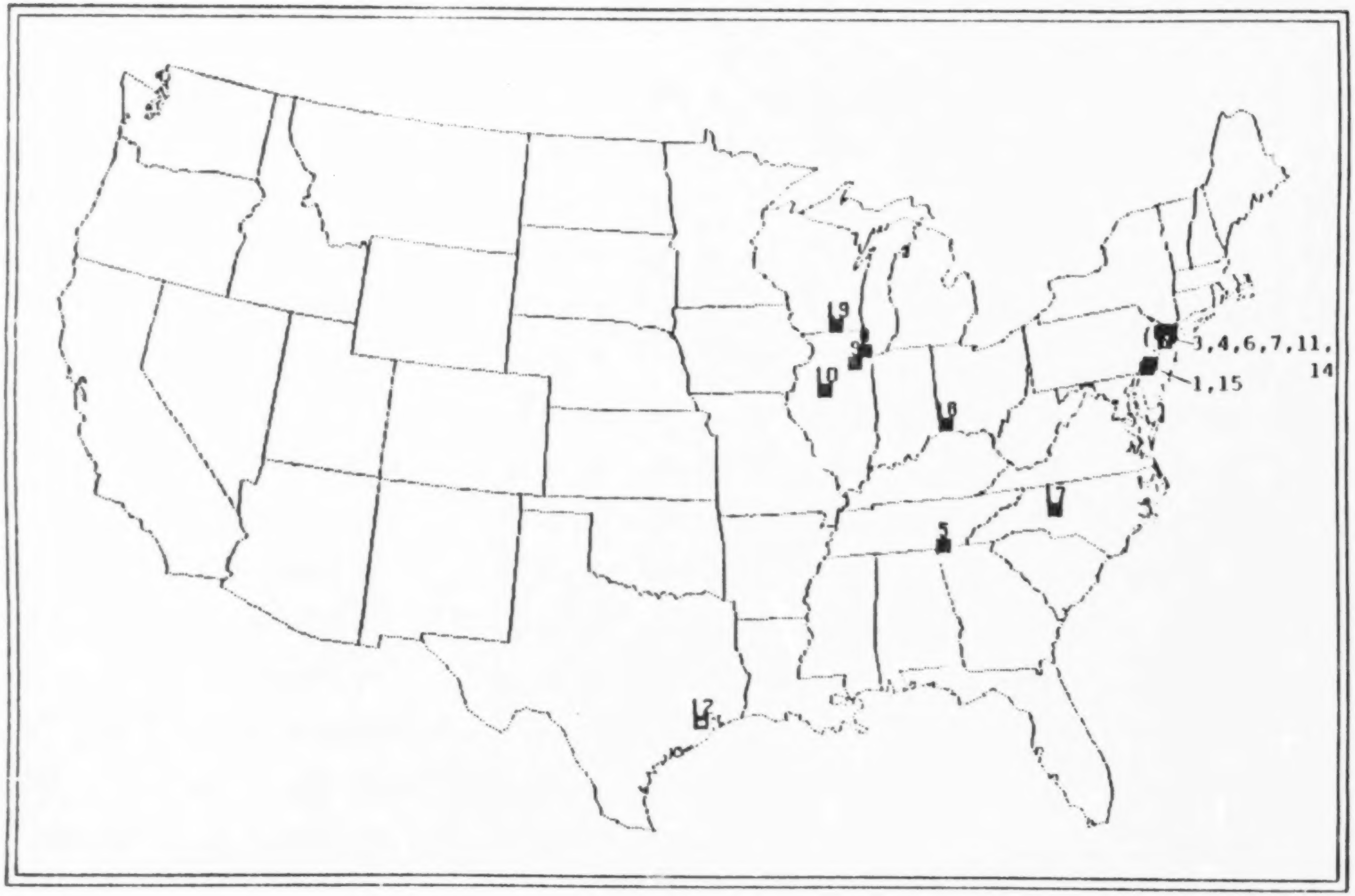

13
9
10
8
2
5
12
3,4,6,7,11,
14
1,15

FIGURE 4-1. SPECIFIC POINT SOURCES OF BENZYL CHLORIDE EMISSIONS

TABLE 4-10. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF BENZYL CHLORIDE

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE† TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	MONSANTO	BRIDGEPORT, NJ	39 47 33	075 23 45	13739	1	1	.202373	.017505	.037598
							2	.067889	.007191	.015534
3	STAUFFER	EDISON, NJ	40 29 23	074 23 03	94741	2	1	.057600	.004954	.01714
4	UOP	E. RUTHERFORD, NJ	40 49 46	074 05 30	94741	2	1	.014400	.001238	.002678
5	VELSICOL	CHATTANOOGA, TN	35 02 31	85 16 36	13882	3	3	.013608	.001555	.004277
6	ORBIS	NEWARK, NJ	40 41 16	074 12 17	94741	3	3	.004032	.000461	.001267
7	NORDA	BOOTEN, NJ	40 54 13	074 24 44	94741	3	3	.004032	.000461	.001267
8	AKZONA	MCCOOK, IL	41 48 17	087 49 41	94846	4	4	.004637	.000662	.001325
9	AKZONA	MORRIS, IL	41 24 24	088 18 10	14855	4	4	.004367	.000662	.001325
10	LONZA	MAPELTON, IL	40 34 00	089 43 01	14842	4	4	.004637	.000662	.001325
11	HEXCEL	LODI, NJ	40 52 00	074 06 50	94741	4	4	.004637	.000662	.001325
12	WITCO	HOUSTON, TX	29 34 45	095 26 00	12906	4	4	.004637	.000662	.001325
13	ASHLAND	JANESEVILLE, WI	42 41 56	089 00 10	14839	4	4	.004637	.000662	.001325
14	GULF OIL	JERSEY CITY, NJ	40 43 02	074 06 14	94741	4	4	.004637	.000662	.001325
15	ROHM & HAAS	PHILADELPHIA, PA	39 54 50	075 11 30	13739	4	4	.004637	.000662	.001325
16	STERLING	CINCINNATI, OH	39 05 15	084 33 09	13840	4	4	.004637	.000662	.001325
17	NATIONAL STARCH	SALISBURY, NC	35 43 34	080 28 19	13728	4	4	.004637	.000662	.001325

[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 4-10. (Concluded)

---

* Plant Types:

Type 1: Plant produces benzyl chloride and butylenzyl phthalate
Type 2: Plant produces benzyl chloride
Type 3: Plant procudes benzyl alcohol
Type 4: Plant produces quaternary ammonium compounds

† Source Types:

Type 1: Benzyl chloride production
Type 2: Butylbenzyl phthalate production
Type 3: Benzyl alcohol production
Type 4: Quaternary ammonium compounds production

TABLE 4-11. EXPOSURE AND DOSAGE OF BENZYL CHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
2.5	1	5
1	10	17
0.5	64	51
0.25	255	114
0.1	2,780	458
0.05	8,691	849
0.025	32,157	1,610
0.01	196,874	3,980
0.005	529,823	6,220
0.0025	1,255,730	8,840
0.001	2,532,018	10,800
9.58×10^{-6}*	31,498,400	16,300

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 4-12. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BENZYL CHLORIDE

Parameter	Value
Daytime decay rate (K_d)	2.8×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.108 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 4-13. BENZYL CHLORIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.000500	446952	261.9	0.	100.0	0.	100.0	0.	0.
.000250	505140	289.4	0.	100.0	0.	100.0	0.	0.
.000100	17551646	3078.7	0.	100.0	0.	100.0	0.	0.
.000050	38996868	4551.8	0.	100.0	0.	99.2	.1	.7
.000025	90835255	6617.8	0.	100.0	0.	97.0	1.4	1.6
.000010	140607011	7511.3	0.	100.0	0.	93.4	2.6	4.0
0.	150679135	7577.7	0.	100.0	0.	92.7	2.7	4.6

TABLE 4-14. EXPOSURE AND DOSAGE SUMMARY OF BENZYL CHLORIDE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
2.5	1	0	0	1	5	0	0	5
1	10	0	0	10	17	0	0	17
0.5	64	0	0	64	51	0	0	51
0.25	255	0	0	255	114	0	0	114
0.1	2,780	0	0	2,780	458	0	0	458
0.05	8,691	0	0	8,691	849	0	0	849
0.025	32,157	0	0	32,157	1,610	0	0	1,610
0.01	196,874	0	0	196,874	3,980	0	0	3,980
0.005	529,823	0	0	529,823	6,220	0	0	6,220
0.0025	1,255,730	0	0	1,255,730	8,840	0	0	8,840
0.001	2,532,018	0	0	2,532,018	10,800	0	0	10,800
0.0005	---	0	446,952	---	---	0	261	---
0.00025	---	0	505,140	---	---	0	289	---
0.0001	---	0	17,551,646	---	---	0	3,080	---
0.00005	---	0	38,996,868	---	---	0	4,550	---
0.000025	---	0	98,835,255	---	---	0	6,620	---
0.00001	---	0	148,607,011	---	---	0	7,510	---
0	31,498,400	0	158,679,135	---	16,300	0	7,580	23,880

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. "Chemical Product Synopsis on Benzyl Chloride," Mannsville Chemical Products, Mannsville, NY (July 1978).

2. 1979 Directory of Chemical Producers, United States, Stanford Research Institute, Menlo Park, CA.

3. "Chemical Product Synopsis on Benzyl Alcohol," Mannsville Chemical Products, Mannsville, NY (July 1978).

4. State of New Jersey, Department of Environmental Protection, Bureau of Air Pollution Control, files on Universal Oil Products, E. Rutherford, New Jersey.

5. State of New Jersey, Department of Environmental Protection, Bureau of Air Pollution Control, files on Stauffer Chemical Company, Edison, New Jersey.

6. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, OH, by Monsanto Research Corporation, Dayton, OH (April 1976).

7. Monsanto Company (C.D. Mallock) personal communication in response to publication of the second draft of this report (February 1982).

APPENDIX A-5 ----- Beryllium

BERYLLIUM CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 744-04-17

Synonyms: Glucinium

Chemical Formula

Molecular Weight: 9.012 (atomic)

Molecular Formula: Be - atomic number: 4

Molecular Structure: Gray metal, close-packed hexagonal structure, anisotropic

Chemical and Physical Properties

Physical State at STP: hard, non-corrosible gray metal

Boiling Point: 2970°C at 5 mm

Melting Point: 1278°C

Density: 1.848 at 20°C/4°C

Vapor Pressure: N/A

Vapor Density: N/A

Solubility: Insoluble

Log Partition Coefficient (Octanol/H_2O): N/A

Atmospheric Reactivity

Transformation Products: (depend upon aerosol size range and growth characteristics) Metal resistant to attack by acid due to the formation of a thin oxide film.

$$\left.\begin{array}{l}\text{Reactivity Toward OH}\cdot\text{:}\\ \text{Reactivity Toward } O_3\text{:}\\ \text{Reactivity Toward Photolysis:}\end{array}\right\}\text{ unreactive}$$

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Bertrandite ore is the major source for beryllium mineral produced in the United States. Production data for beryllium have not been reported in recent years in order to avoid disclosing individual company confidential data.[1]

Only one site, Brush Wellman, Inc., in Millard County, Utah, processes bertrandite ore and converts it to beryllium hydroxide. Brush Wellman processes both domestic bertrandite ore, mined at its delta facility, and imported beryl ore for Kawecki-Berylco. The beryllium hydroxide resulting from the processing of the imported beryl ore is then upgraded by Kawecki-Berylco at its plants in Hazelton and Reading, Pennsylvania.[1,2] Small quantities of beryl ore have reportedly been mined in South Dakota and Arizona.

In 1976, the last year for which data are available, 7.5 million lb of beryllium was used in the United States. Of this quantity, approximately 2.1 million lb was imported from other countries, and the remaining 5.4 million lb was obtained from stockpiles and production.[2]

B. USES

The primary end-use of beryllium is in the manufacture of beryllium-copper alloys. An estimated 75% (5.6 million lb) is consumed for this end-use. Beryllium metal production consumed an estimated 18% (1.35 million lb), and beryllium oxide consumed the remaining 7% (0.55 million lb). Uses are summarized in Table 5-1.[2] There have been no reported exports of beryllium since 1964. Source locations for the major beryllium metal and alloy sites are shown in Table 5-2.[3,4] Total beryllium use in metal and alloy manufacture was allocated based on the number of employees at each site.

C. INCIDENTAL SOURCES

Incidental sources of beryllium emissions include coal- and oil-fired boilers, coke ovens, and the gray iron foundry industry. The boilers include industrial, power plant, commercial, and residential types. Beryllium emissions originate as impurities from oil and coal when they are burned in the boilers or in coke ovens or as diesel fuel. Table 5-3 shows the estimated consumption of oil and coal in 1978 by category. Table 5-4 indicates, by region, the percent of coal and oil used by power plants.

Table 5-1. Beryllium End-Use 1978[a]

Use	Usage (10^6 lb/yr)	Usage (%)
Beryllium-copper alloys	5.6	75
Beryllium metal	1.35	18
Beryllium-oxide ceramics	0.55	7
Total	7.5	100

[a] See ref. 2.

Table 5-2. Beryllium Metal and Alloy Producers[a]

Company	Location	Beryllium Metal/ Alloy Capacity (lb/yr)	Beryllium Used[b] (lb/yr)	Geographical Location Latitude/Longitude
Brush Wellman	Elmore, OH	NA	2.39	41 28 06/83 16 37
	Reading, PA	NA	0.57	40 46 45/73 11 10
	Hampton, NJ	NA	0.28	40 42 32/74 57 41
Kawecki Berylco Industries	Hazelton, PA	NA	2.16	40 21 28/75 57 10
	Reading, PA	NA	1.55	40 47 32/73 11 50
Total			6.95	

---

[a] See refs. 3 and 4.

[b] Total beryllium usage distributed over the sites based on the number of people employed.

Table 5-3. 1978 United States Oil and Coal Consumption*

User	Coal Consumption (million tons)	Oil Consumption (million bbls)
Electrical utilities	480	646
Industry	55	671
Coke ovens	75	-
Residential commercial	8	707
Diesel fuel	-	327
Total	618	2351

*See refs 5 and 6.

Table 5-4. Electrical Utility Power Plant Locations and Usage of Coal and Oil by Geographic Region*

Region	Number of Sites	Percentage of Total U.S. Coal Consumption	Number of Sites	Percentage of Total U.S. Oil Consumption
New England	9	0.7	35	9.4
Middle Atlantic	51	11.3	70	27.9
East North Central	156	33.9	110	5.9
West North Central	111	9.4	85	0.7
South Atlantic	61	19.6	97	31.4
East South Central	44	16.3	26	2.0
West South Central	3	1.3	100	4.8
Mountain	38	6.8	44	2.2
Pacific	1	0.7	33	15.7
Total	474	100.0	600	100.0

*See ref. 7.

II. EMISSION ESTIMATES

A. PRODUCTION

The primary source of emission data for this summary was the Survey of Emissions and Controls for Hazardous and Other Pollutants prepared for the Environmental Protection Agency by the Mitre Corp.[8] In this report, it is estimated that emissions resulting from ore mining and processing, use as beryllium oxide, and use in beryllium metal fabrication are negligible due to control techniques. The only significant sources of beryllium emissions are in beryllium alloy and compound manufacture and from the incidental sources noted in Section I.

B. USES

Beryllium emissions from beryllium metal and alloy manufacture are shown in Table 5-5.[3,4,8] Total emissions were derived by multiplying the emission factor of 0.000785 lb beryllium lost per lb used from the Mitre report[8] times the beryllium used. Total beryllium emissions from this end-use are estimated to have been 5455 lb.

C. INCIDENTAL

Beryllium emissions resulting from gray iron foundry operations are shown in Table 5-6 by geographic region. They totaled 8,000 lb. Emissions were estimated by multiplying the emission factor 0.000444 lb/ton[8] times the estimated production of 18,000,000 tons of metal. The total emissions were then distributed by region based on the total number of employees in gray iron foundry operations in each region.[9]

Beryllium emissions resulting from electrical utility power plants are shown for coal-fired operations in Table 5-7 and for oil-fired operations in Table 5-8. Coal-fired plants had emissions of 240,000 lb, and oil-fired plants had emissions of 9500 lb.

These emissions were calculated by multiplying the emission factors shown in Tables 5-7 and 5-8 by the coal and oil used shown in Table 5-3. The emissions were distributed by region according to the usage percentages shown in Table 5-4.

Table 5-5. Beryllium Emissions from Beryllium Metal and Allyol Production[a]

Company	Location	Beryllium Used (lb/yr)[b]	Beryllium Emissions[c]	
			(lb/yr)	(g/sec)[d]
Brush Wellman	Elmore, OH	2.39	1875	0.027
	Reading, PA	0.57	450	0.006
	Hampton, NJ	0.28	220	0.003
Kawecki-Berylco	Hazelton, PA	2.16	1695	0.024
	Reading, PA	1.55	1215	0.017
Total		6.95	5455	

[a] See refs. 3 and 4.

[b] Total beryllium usage allocated per site based on the number of employees at each site.

[c] Based on emission factor of 0.000785 lb beryllium lost per lb used. C - derived from published source. See ref. 8.

[d] Assumes 8760 hr/yr operation.

Table 5-6. Beryllium Emissions from Gray Iron Foundry Operations[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site	
			(lb/yr)	(g/sec)[b]
New England	13	200	15.4	0.0002
Middle Atlantic	42	735	17.5	0.0003
East North Central	129	4170	32.3	0.0005
West North Central	29	455	15.7	0.0002
South Atlantic	22	590	26.8	0.0004
East South Central	37	944	25.5	0.0004
West South Central	19	400	21.0	0.0003
Mountain	5	95	23.8	0.0003
Pacific	28	408	14.5	0.0002
Total	324	8000[c]		

[a] See ref. 9.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.000444 lb beryllium lost per ton of metal produced. C - derived from published data. See ref. 8.

Table 5-7. Beryllium Emissions from Electrical Utilities Power Plants Coal-fired[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	9	1,680	190	0.003
Middle Atlantic	51	27,120	530	0.008
East North Central	156	81,360	520	0.007
West North Central	111	22,560	200	0.003
South Atlantic	61	47,040	770	0.011
East South Central	44	39,120	890	0.013
West South Central	3	3,120	1040	0.015
Mountain	38	16,320	430	0.006
Pacific	1	1,680	1680	0.024
Total	474	240,000[c]	506	

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on 0.00000025 lb beryllium emitted per lb coal burned. C - derived from published data. See ref. 8.

Table 5-8. Beryllium Emissions from Electrical Utility Power Plants Cil-fired[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	35	893	25.5	0.0004
Middle Atlantic	70	2650	37.9	0.0005
East North Central	110	560	5.1	nil
West North Central	85	67	0.8	nil
South Atlantic	97	2983	30.8	0.0004
East South Central	26	190	7.3	0.0001
West South Central	100	456	4.6	nil
Mountain	44	209	4.8	nil
Pacific	33	1492	45.2	0.0007
Total	600	9500[c]	15.8	

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on 0.00000035 lb beryllium emitted per gallon oil burned. C - derived from published data. See ref. 8.

Beryllium emissions from coke oven operations were estimated to be 37,500 lb as shown in Table 5-9. This estimate is based on the coal emission factor derived for power plants.[8] Total emissions were distributed by the number of sites in each region.[10]

The remaining incidental sources of beryllium emissions are from other sources that burn oil or coal. The emission factors used were the same as for power plant emission estimates. Emissions from oil- and coal-fired industrial boilers were estimated to have been 27,500 lb and 9870 lb respectively. Emissions from residential and commercial oil and coal heating were estimated to be 4,000 lb and 10,400 lb respectively. Diesel fuel consumption generated an estimated 4810 lb of beryllium emissions. Source locations for all these incidental categories are considered too numerous and too diverse to pinpoint regional distributions.

Vent parameter data for all beryllium emission sources are shown in Table 5-10.

Table 5-11 presents a summary of beryllium emissions. Total nationwide beryllium emissions are estimated to have been 357,035 lb in 1978.

Table 5-9. Beryllium Emissions from Coke Oven Operations[a]

Region	Number of Sites	Beryllium Emissions (lb/yr)
New England	0	0
Middle Atlantic	15	9,220
East North Central	25	15,370
West North Central	3	1,845
South Atlantic	4	2,460
East South Central	9	5,530
West South Central	2	1,230
Mountain	2	1,230
Pacific	1	615
Total	61	37,500[b,c]

[a] See ref. 10.

[b] Based on an emission factor of 0.00000025 lb lost/lb coal burned. See ref. 8.

[c] Average emission per site 615 lb/yr (0.009 g/sec).

Table 5-10. Beryllium Vent Parameters[*]

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Power plants	1	400	16	200	90
Gray iron foundry	1	150	2	200	40
Alloy manufacture	2	40	1	140	10
Coke oven	2	30	1	300	15

[*]Building cross-section for all sources - 200 m^2.

Table 5-11. 1978 Beryllium Nationwide Emissions

Source	Estimated Nationwide Emissions (lb/yr)
Producers	Negligible
Beryllium metal, alloys, and compounds	5,455
Beryllium fabrication	Negligible
Beryllium oxide-ceramics	Negligible
Gray iron foundries	8,000
Electrical utility	
Power plant boilers	
Coal	240,000
Oil	9,500
Industrial boilers	
Coal	27,500
Oil	9,870
Residential/commercial boilers	
Coal	4,000
Oil	10,400
Coke ovens (coal)	37,500
Diesel fuel (oil)	4,810
Total	357,035

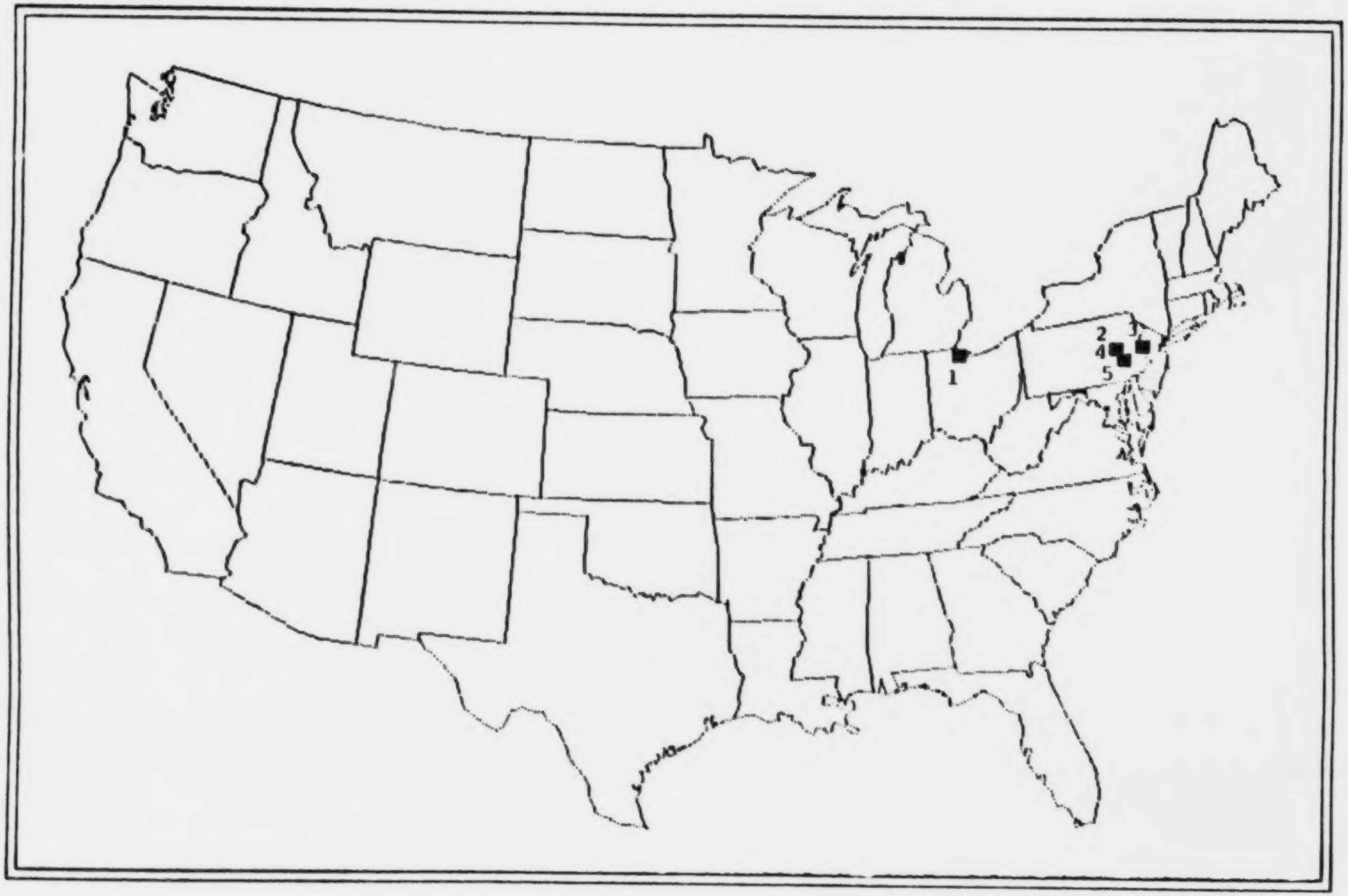


FIGURE 5-1. SPECIFIC POINT SOURCES OF BERYLLIUM EMISSIONS

TABLE 5-12. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF BERYLLIUM

No.	Company	Site	Latitude	Longitude	Star Station	Plant* Type	Source† Type	Emissions (gm/sec) Process	Storage	Fugitive
1	Brush Wellman	Elmor, OH	41 28 06	083 16 37	94830	1	1	.027000	0.1875	0.
2	Brush Wellman	Reading, PA	40 46 45	076 11 10	14712	1	1	.006480	0.450	0.
3	Brush Wellman	Hampton, NJ	40 42 32	074 57 41	94741	1	1	.003168	0.220	0.
4	Kawecki-Berylco	Reading, PA	40 47 32	076 11 50	14712	1	1	.024408	0.695	0.
5	Kawecki-Berylco	Hazelton, PA	40 21 28	075 57 10	14737	1	1	.017496	0.1215	0.

---

[*] All the emissions of beryllium are from metal and alloy production sites with the following emissions parameters:

Vent height = 12 m
Building cross-section = 200 m^2
Vent diameter = 0.3 m
Vent velocity - 3 m/sec
Vent temperature = 333 °K

TABLE 5-13. EXPOSURE AND DOSAGE OF BERYLLIUM RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
0.25	102	32
0.1	562	108
0.05	1,298	160
0.025	3,042	225
0.01	8,937	314
0.005	32,669	472
0.0025	74,596	618
0.001	176,030	770
5.0×10^{-6}*	720,266	923

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 5-14. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF BERYLLIUM

Region	Gray Iron Foundry		Power Plant (Coal)		Power Plant (Oil)		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00022	13	0.00274	9	0.00037	35	0	0
Middle Atlantic	0.00025	42	0.00763	51	0.00055	70	0.00885	15
East North Central	0.00047	129	0.00749	156	0.000073	110	0.00885	25
West North Central	0.00023	29	0.00288	111	0.000012	85	0.00885	3
South Atlantic	0.00039	22	0.0111	61	0.00044	97	0.00885	4
East South Central	0.00037	37	0.0128	44	0.00011	26	0.00885	9
West South Central	0.00030	19	0.0150	3	0.000066	100	0.00885	2
Mountain	0.00034	5	0.0062	38	0.000069	44	0.00885	2
Pacific	0.00021	28	0.00242	1	0.00065	33	0.00885	1

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TABLE 5-15. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF BERYLLIUM

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)					Dosage [$10^3(\mu g/m^3)$ • persons]				
	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total
0.1	0	0	0	1.3	1.3	0	0	0	0.15	0.15
0.05	0	0	0	14	14	0	0	0	0.9	0.9
0.025	0	0	0	80	80	0	0	0	3	3
0.01	0	40	0	464	504	0	0.5	0	9	9
0.005	0	410	0	1,200	1,610	0	3	0	14	17
0.0025	--	--	--	--	--	0	10	0	20	30
0.001	--	--	--	--	--	0.02	19	0	28	47
0.0005	--	--	--	--	--	0.3	29	0.05	36	65
0.00025	--	--	--	--	--	0.7	37	0.12	44	82
0	--	--	--	--	--	6.4	81	3.2	55	145

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 5-16. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF BERYLLIUM

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0.203 gm/sec
Residential/commercial coal-burning	0.058 gm/sec
Residential/commerical oil-burning	0.145 gm/sec
Nationwide nonheating stationary source emissions (E_N)	0.538 gm/sec
Coal-burning	0.396 gm/sec
Oil-burning	0.142 gm/sec
Nationwide mobile source emissions (E_M)	0.0693 gm/sec
Ratio of truck emissions to auto emissions (R_M)	3.0

TABLE 5-17. BERYLLIUM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Exposure Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
0.002500	505,140	1,758.9	13.8	82.4	3.8	100.0	0.	0.
0.001000	9,149,730	16,754.3	30.8	66.6	2.6	100.0	0.	0.
0.000500	28,601,329	30,552.2	28.9	66.7	4.4	100.0	0.	0.
0.000250	73,351,092	45,256.6	27.7	67.2	5.1	97.8	0.8	1.3
0.000100	139,664,753	56,842.5	26.9	67.4	5.8	94.2	2.5	3.3
0.	158,679,135	53,136.8	26.8	67.4	5.8	92.8	2.6	4.6

TABLE 5-18. EXPOSURE AND DOSAGE SUMMARY OF BERYLLIUM

Concentration Level (µg/m^3)	Population Exposed (persons)				Dosage [(µg/m^3) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
0.25	102	0	0	102	32	0	0	32
0.1	562	1,300	0	1,862	108	150	0	258
0.05	1,298	14,000	0	15,298	160	900	0	1,060
0.025	3,042	80,000	0	83,042	225	3,000	0	3,225
0.01	8 937	504,000	0	512,937	314	9,000	0	9,314
0.005	32,669	1,610,000	0	1,642,669	472	17,000	0	17,472
0.0025	74,596	--	505,140	74,596	618	30,000	1,759	32,377
0.001	176,030	--	9,149,730	176,030	770	47,000	16,754	64,524
0.0005	--	--	28,601,329	--	--	65,000	30,552	--
0.00025	--	--	73,351,092	--	--	82,000	45,257	--
0.0001	--	--	139,664,758	--	--	--	56,843	--
0	720,266	--	158,679,135	--	923	145,000	58,100	204,023

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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8. Survey of Emissions and Controls for Hazardous and Other Pollutants, the Mitre Corp., EPA Contract No. 68-01-0438, p. 103.

9. Marketing Economics Key Plants 1975-1976, Marketing Economics Institute, New York, New York.

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APPENDIX A-6 ----- Carbon Tetrachloride

CARBON TETRACHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 56-23-5

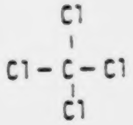
Synonyms: Tetrachloromethane; Perchloromethane; Methane Tetrachloride; Necatorina; Benzinoform

Chemical Formula

Molecular Weight: 153.82

Molecular Formula: CCl_4

Molecular Structure:



$$\begin{array}{c} Cl \\ | \\ Cl - C - Cl \\ | \\ Cl \end{array}$$

Chemical and Physical Properties

Physical State at STP: Liquid - colorless, nonflammable

Boiling Point: 76.54°C at 760 mm

Melting Point: -22.99°C

Density: 1.5940 at 20°C/4°C

Vapor Pressure: 115.2 mm at 25°C

Vapor Density: 5.32

Solubility: Soluble (0.77 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.64

Atmospheric Reactivity

Transformation Products: None - NAPP

Reactivity Toward OH·: Extremely slow

Reactivity Toward O_3: Extremely slow

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: Chlorinated hydrocarbons

Formation Reactivity:

I. SOURCES

Four volatile organic compounds—methyl chloride, methylene chloride, chloroform, and carbon tetrachloride—comprise the group of chemicals commonly referred to as the chloromethanes.

Carbon tetrachloride (CCl_4) can be produced by a variety of processes including the chlorination of carbon disulfide, methane, and methyl chloride, or the chlorinolysis of mixed hydrocarbons.

In 1978 six companies at ten locations in the U.S. produced an estimated 750 million lb of carbon tetrachloride. The locations of the plants, the type of production process used, and the 1978 capacity and estimated production level for each plant are shown in Table 6-1.[4,8,9]

The major end-use for carbon tetrachloride is in the production of the fluorocarbon gases trichlorofluoromethane (F-11) and dichlorodifluoromethane (F-12). An estimated 55% (412.5 million lb) of carbon tetrachloride was used to make F-12 and an estimated 255.0 million lb was used to make F-11 in 1978.

The remaining carbon tetrachloride production (60.0 million lb) was used in solvent applications as an oil, wax, and fat extractant; in rubber cement; in shoe and furniture polishes; in paints and lacquers; in printing ink; in floor waxes; in stains; and in pesticide manufacture.

An estimated 3% of the total production amounting to 22.5 million lb of carbon tetrachloride was exported. End-uses for carbon tetrachloride are summarized in Table 6-2.[6]

II. EMISSION ESTIMATES

PRODUCTION

Estimated emission losses from the production of carbon tetrachloride for each location is shown in Table 6-3.[1,2] Total emissions of methylene chloride, chloroform, and carbon tetrachloride from production facilities are estimated to have been 645,914 lb, 351,280 lb, and 4,141,360 lb respectively in 1978. These estimates are based on the emission factors generated for each of the four processes used in the industry.[1,2,10] Other associated emission components include methyl chloride and hydrogen chloride from the methyl chloride and methane chlorination processes and perchloroethylene, ethylene source locations

TABLE 6-1. Production of Carbon Tetrachloride[a]

Source[b]	Location	1978 Estimated Production[c] (10^6 lb/yr)	Process[d]	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical Corp.	Moundsville, WV	4	A,B[e]	8	39 54 24/80 47 51
Dow Chemical	Freeport, TX	70	B	135	28 59 15/95 24 45
	Pittsburg, CA	42	C	80	37 59 34/121 54 56
	Plaquemine, LA	65	C	125	30 19 00/91 15 00
Du Pont	Corpus Christi, TX	213	C	410	27 53 00/97 15 00
FMC Corp.	S. Charleston, WV	156	D	300	38 22 10/81 40 03
Stauffer Chemical	LeMoyne, AL	104	D	200	30 53 50/87 58 50
	Louisville, KY	18	C	35	38 12 09/85 51 49
Vulcan Materials Co.	Geismar, LA	47	C	90	30 10 00/90 59 00
	Wichita, KS	31	C	60	37 36 55/97 18 30
Total		750		1443	

[a] See refs. 4, 8, and 9.

[b] FMC Corp. has announced that it is shutting down its 300 million pound per year plant in S. Charleston, WV, in September 1979.

[c] Distribution of the 750 million pounds per year for each producing location has been made as a direct ratio of total production/total capacity X plant capacity.

[d] (A) - Methyl chloride chlorination.
(B) - Methane chlorination.
(C) - Chlorinolysis of mixed HC feed with perchlor co-product.
(D) - Carbon disulfide chlorination.

[e] 5% methane chlorination, 95% methyl chloride chlorination.

TABLE 6-2. 1978 Carbon Tetrachloride Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Dichlorodifluoromethane (F-12)	55	412.5
Trichlorofluoromethane (F-11)	34	255.0
Solvents and miscellaneous	8	60.0
Export	3	22.5
Total	100	750.0

*See ref. 6.

TABLE 6-3. 1978 Carbon Tetrachloride Production Emissions

Company	Location	Process Vent Emissions (lb/yr)	Process Vent Emissions (g/sec)[b]	Storage Vent Emissions (lb/yr)	Storage Vent Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied Chemical	Moundsville, WV	20	Nil	510	0.007	290	0.004	820	0.012
Dow Chemical	Freeport, TX	370	0.005	8,800	0.128	5,030	0.072	14,200	0.206
	Pittsburg, CA	350	0.005	70,140	1.010	20,580	0.296	91,070	1.311
	Plaquemine, LA	550	0.008	108,550	1.563	31,850	0.459	140,950	2.029
Dupont	Corpus Christi, TX	1,790	0.026	355,710	5.121	104,370	1.503	461,870	6.649
FMC	South Charleston, WV	1,560,000	22.458	530,400	7.636	93,600	1.347	2,184,000	31.441
Stauffer	Lemoyne, AL	743,000	10.694	252,600	3.636	44,600	0.641	1,040,000	14.971
	Louisville, KY	150	0.002	30,060	0.433	8,820	0.127	39,030	0.562
Vulcan	Geismar, LA	400	0.006	78,490	1.130	23,030	0.332	101,920	1.467
	Wichita, KA	260	0.004	51,770	0.745	15,190	0.219	67,220	0.968
Total		2,306,890		1,487,110		347,360		4,141,360	

[a] Derived from the emission factors shown in Table 10.

[b] Based on 8760 hr/yr operation.

source locations for fluorocarbons 11 and 12 manufacture are shown in Table 6-4.[13] Also shown in that table are the production quantities for fluorocarbons 11 and 12 and the corresponding carbon tetrachloride manufacturing requirement.

Emission estimates of carbon tetrachloride from these sites are shown in Table 6-5.[14] Total estimated emissions of carbon tetrachloride from fluorocarbon 11 and 12 production sites are estimated to be 333,360 lb. Other associated emissions from these sites would incude other halocarbons used as feed materials and the various fluorocarbons produced. Vent parameter data relative to carbon tetrachloride emissions from fluorocarbons 11 and 12 production are shown in Table 8-7. Carbon tetrachloride emissions originate from two process distillation vents and four storage tanks.

The remaining carbon tetrachloride (60.0 million lb) consumed for solvent applications is eventually released to the atmosphere. Specific source locations could not be identified. Emissions from exports were assumed to be negligible.

Total annual nationwide emissions of carbon tetrachloride are estimated to be 64,500,000 lb. A tabulation of the losses is shown in Table 6-6.

Table 6-4. **Users of Carbon Tetrachloride and Chloroform to Produce Fluorocarbons**

	Flurorocarbon Annual Capacity (10^6 lb)	Estimated 1978 Production F-11 (10^6 lb)	Estimated 1978 Production F-12 (10^6 lb)	Estimated 1978 Production F-22 (10^6 lb)	Estimated Production Totals (10^6 lb)	Carbon Tetra-chloride Used (10^6 lb)	Chloro-form Used (10^6 lb)	Geographic Coordinates Latitude/Longitude
Allied Chemical								
Baton Rouge, LA	310	Assumed shut down						
Danville, IL		28.5	40.6		282.9	87.3		40 08 30/87 33 45
Elizabeth, NJ		28.5	40.6	37.8		87.3	55.7	40 40 45/74 13 51
El Segundo, CA		28.5	40.6	37.8		87.3	55.7	33 56 30/118 26 35
Du Pont								
Antioch, CA	400	36.8	52.3		364.9	112.6		37 59 37/121 52 00
Deepwater, NJ		36.8	52.3	48.8		112.6	71.9	39 41 25/75 30 35
Montague, MI		36.8	52.3			112.6		43 24 10/86 23 40
Louisville, KY				48.8			71.9	38 11 51/85 54 13
Corpus Christi, TX								27 53 00/97 15 00
Pennwalt Corp.								
Calvert City, KY	80	22.1	31.4	19.5	73.0	67.6	28.6	37 03 18/88 19 40
Thorofare, NJ	35	Assumed shutdown						
Union Carbide								
Institute and S. Charleston, WV	Not listed	Assumed shutdown						
Essex Chemical Corp. (Racon)								
Wichita, KS	20							
Kaiser Aluminum & Chemical Corp.								
Gramercy, LA	80							
Total	925	218	310.1	192.7	720.8	667.5	283.8	

*See ref. 13.

Table 6-5. Emissions from Carbon Tetrachloride and Chloroform Users for Flurocarbon Production[a]

Source	Location	F-11/F-12 Carbon Tetrachloride Emissions (lb/yr)[b]	F-11/F-12 Carbon Tetrachloride Emissions (g/sec)[d]	F-22 Chloroform Emissions (lb/yr)[c]	F-22 Chloroform Emissions (g/sec)[d]
Allied[e]	Danville, IL	58,460	0.84	0	
	Elizabeth, NJ	0	0	16,350	0.24
	El Segundo, CA	3,400	0.05	100	0.001
Du Pont	Antioch, CA	75,420	1.09	0	0
	Deepwater, NJ	75,420	1.09	148,800	2.14
	Montague, MI	75,420	1.09	0	0
	Louisville, KY	0		148,800	2.14
Pennwalt	Calvert City, KY	45,240	0.65	59,410	0.86
Total		333,360		373,460	

[a] See ref. 14.

[b] Based on the following emission factor, except where noted:

Process	0.000449	A - (derived from site visit)
Storage	0.000442	A - (derived from site visit)
Fugitive	0.000178	A - (derived from site visit)
	0.001069	

[c] Based on the following emission factor, except where noted:

Process	0	A - (derived from site visit)
Storage	0.00374	A - (derived from site visit)
Fugitive	0.00075	A - (derived from site visit)
	0.00449	

[d] Assumes 8760 hours/year operation.

[e] Allied Company has supplied their own emissions estimates.[15]

Table 6-6. Estimated Carbon Tetrachloride Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	
Dichlorodifluoromethane (F-12)	4.14
Trichlorofluoromethane	0.36
Solvents, miscellaneous	60.0
Export	0
Total	64.5

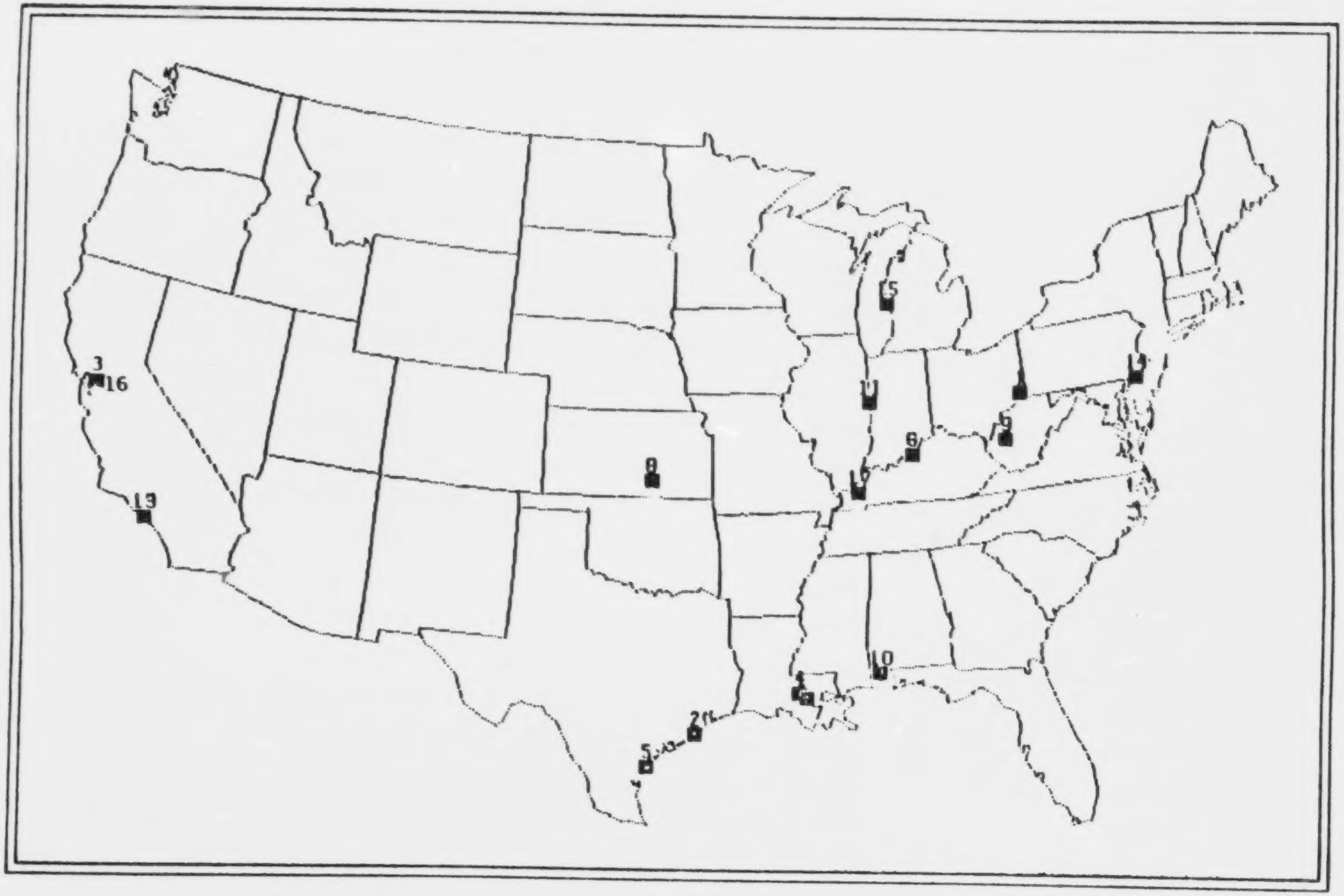

3
16
13
8
15
6
9
14
10
2
5
7

FIGURE 6-1. SPECIFIC POINT SOURCES OF CARBON TETRACHLORIDE EMISSIONS

TABLE 6-7. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CARBON TETRACHLORIDE

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	1	1	.000288	.007344	.004176
2	DOW CHEMICAL	FREEPORT, TX	28 59 32	095 23 35	12923	2	2	.005328	.127872	.072432
3	DOW CHEMICAL	PITTSBURG, CA	37 59 34	121 54 56	23202	3	3	.005040	1.010016	.296352
4	DOW CHEMICAL	PLAQUEMINE, LA	30 19 00	091 15 00	13970	3	3	.007920	1.563120	.458640
5	DUPONT	CORPUS CRISTI, TX	27 53 00	097 15 00	12925	3	3	.025776	5.122224	1.502928
6	STAUFFER	LOUISVILLE, KY	38 12 09	085 51 49	93820	3	3	.002160	.432864	.127008
7	VULCAN	GEISMAR, LA	30 10 00	090 59 00	12958	3	3	.005760	1.130256	.331632
8	VULCAN	WICHITA, KA	37 36 55	097 18 30	03928	3	3	.003744	.745488	.218736
9	FMC	SO CHARLESTON, WV	38 22 10	081 40 03	13866	4	4	22.464000	7.637760	1.347840
10	STAUFFER	LEMOYNE, AL	30 53 50	087 58 50	93841	4	4	14.976000	5.091840	.898560
11	ALLIED	DANVILLE, IL	40 08 30	087 33 45	14806	5	5	.353520	.348048	.139680
13	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129	5	5	0.0	.048903	0.0
14	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	5	5	.456192	.448992	.180864
15	DUPONT	MONTAGUE, MI	43 24 10	086 23 40	14840	5	5	.455040	.448992	.180864
16	DUPONT	ANTIOCH, CA	37 59 37	121 52 00	23202	5	5	.456192	.448992	.180864
17	PENNWALT	CALVERT CITY, KY	37 03 18	088 19 40	03816	5	5	.273600	.269280	.108432

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[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 6-7 (Concluded)

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* Plant Types:

Type 1: Plant produces carbon tetrachloride by using the methyl chloride chlorination process

Type 2: Plant produces carbon tetrachloride by using the methane chlorination process

Type 3: Plant produces carbon tetrachloride by using the chlorinolysis process

Type 4: Plant produces carbon tetrachloride by using the carbon disulfide chlorination process

Type 5: Plant produces flurocarbons

† Source Types:

Type 1: Methyl chloride chlorination process

Type 2: Methane chlorination process

Type 3: Chlorinolysis process

Type 4: Carbon disulfide chlorination processes

Type 5: Flurocarbons production process

/

TABLE 6-8. EXPOSURE AND DOSAGE OF CARBON TETRACHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
500	66	36,900
250	403	154,000
100	1,615	332,000
50	3,762	474,000
25	8,048	622,000
10	23,396	863,000
5	35,821	949,000
2.5	60,945	1,040,000
3.8×10^{-5}*	5,195,587	1,280,000

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 6-9. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CARBON TETRACHLORIDE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	864 gm/sec
Nationwide mobile source emissions	0

TABLE 6-10. CARBON TETRACHLORIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
2.500000	505140	2327358.7	0.	100.0	0.	100.0	0.	0.
1.000000	9149730	17913784.0	0.	100.0	0.	100.0	0.	0.
.500000	33072205	35194859.0	0.	100.0	0.	100.0	0.	0.
.250000	83219704	51528284.4	0.	100.0	0.	98.1	.7	1.2
.100000	142920535	61879083.9	0.	100.0	0.	94.0	2.5	3.5
0.	150679135	62926289.6	0.	100.0	0.	92.9	2.6	4.5

TABLE 6-12. EXPOSURE AND DOSAGE SUMMARY OF CARBON TETRACHLORIDE

Concentration Level (μg/m^3)	Population Exposed (persons)				Dosage [(μg/m^3)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
620	15	0	0	15	9,420	0	0	9,420
500	66	0	0	66	36,900	0	0	36,900
250	403	0	0	403	154,000	0	0	154,000
100	1,615	0	0	1,615	332,000	0	0	332,000
50	3,762	0	0	3,762	474,000	0	0	474,000
25	8,048	0	0	8,048	622,000	0	0	622,000
10	23,396	0	0	23,396	863,000	0	0	863,000
5	35,821	0	0	35,821	949,000	0	0	949,000
2.5	60,945	0	**505,140**	566,085	1,040,000	0	**2,327,400**	3,367,400
1	112,556	0	**9,149,730**	9,262,286	1,120,000	0	**17,913,784**	19,033,784
0.5	187,202	0	**33,072,205**	33,259,407	1,180,000	0	**35,194,859**	36,374,859
0.25	--	0	**83,219,704**	--	--	0	**51,528,284**	--
0.1	--	0	**142,928,535**	--	--	0	**61,879,083**	--
3.8x10^{-5}	5,195,587	0	**158,679,135**	--	1,280,000	0	**62,926,300**	64,456,300

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-7 ----- Chlorobenzene (p-Dichlorobenzene and o-Dichlorobenzene)

CHLOROBENZENE (MONO) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-90-7

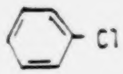
Synonyms: Phenyl Chloride; Monochlorobenzene; Chorobenzol; Benzene Chloride

Chemical Formula

Molecular Weight: 112.56

Molecular Formula: C_6H_5Cl

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid-colorless, very refractive

Boiling Point: 131.7°C at 760 mm

Melting Point: -45.6°C

Density: 1.1053 at 20°C/4°C

Vapor Pressure: 12.14 mm at 25°C

Vapor Density: 3.88

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.84

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/3 Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

o-DICHLOROBENZENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-50-1

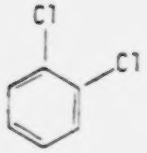
Synonyms: DCB; Dichlorobenzol; 1,2-Dichlorobenzene; o-Dichlorobenzol; ODB; ODCB; Chloroben; Cloroben; Dizene; Dowthern E

Chemical Formula

Molecular Weight: 147.0

Molecular Formula: $C_6H_4Cl_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless

Boiling Point: 180.5°C at 760 mm

Melting Point: -17°C

Density: 1.305 at 20°C/4°C

Vapor Pressure: 1.45 at 25°C

Vapor Density: 5.05

Solubility: Slightly soluble (0.145 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.38

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/2 Butane

Reactivity Toward O_3: 5% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

p-DICHLOROBENZENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-50-1

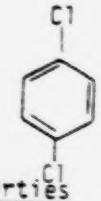
Synonyms: DCB; Dichlorobenzol; Paradichlorobenzene; Parazene; Paramoth; Di-chloricide; Paracide; Paradi; Paradow; Santochlor

Chemical Formula

Molecular Weight: 147.0

Molecular Formula: $C_6H_4Cl_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Monoclinic crystals - volatile

Boiling Point: 174.12°C

Melting Point: 53.5°C

Density: 1.288 at 20°C/4°C

Vapor Pressure: 2.28 at 25°C

Vapor Density:

Solubility: Nearly insoluble (0.079 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.39

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/2 Butane

Reactivity Toward O_3: 5% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

This report summarizes emissions of chlorobenzenes including monochlorobenzene and the two dichlorobenzene isomers (o-dichlorobenzene and p-dichlorobenzene). Monochlorobenzene is produced by the direct chlorination of benzene using iron as a catalyst. When only monochlorobenzene is desired, the temperature is kept near the lower end of a 40 to 60°C range, and only 60% of the theoretical amount of chlorine is added to lessen the formation of dichlorobenzenes. When dichlorobenzenes are desired, higher chlorine quantities and temperatures are used. The chlorinated benzene is neutralized with aqueous caustic soda, allowed to separate, and the dichlorobenzene-rich sludge that forms is removed. The chlorobenzene layer is then distilled to obtain a fraction containing unreacted benzene and some monochlorobenzene, which is recycled, and chlorobenzene. The higher chlorinated fractions and residues from a number of batches are combined and then distilled to recover para-dichlorobenzene in the distillate and ortho-dichlorobenzene residues which are then purified.

There are currently 6 monochlorobenzene producers in the United States. The locations of the plants and the 1978 capacity and estimated production for each plant are shown in Table 7-1.[1] [2] [3] In 1978, an estimated 355 million lb of monochlorobenzene was produced.

Table 7-2 [3] [4] [5] presents the producers of o-dichlorobenzene in the United States. There are currently 7 sites which produced an estimated 59 million lb of o-dichlorobenzene in 1978.

Table 7-3 [3] [4] [6] presents the producers of p-dichlorobenzene in the United States. There are currently 7 sites which produced an estimated 55 million lb of p-dichlorobenzene in 1978.

B. USES

Table 7-4 summaries the chlorobenzene end-use distribution. The various uses, quantities, and percent usage of monochlorobenzene, o-dichlorobenzene, and p-dichlorobenzene are shown. Approximately 49% of the monochloobenzene produced is used in solvents and 30% is used in nitrochlorobenzenes. Other uses

Table 7-1. Monochlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	101	220	43 35 28/84 13 08
ICC	Niagra Falls, NY	5	10	43 03 33/79 00 55
Monsanto	Sauget, IL	69	150	38 35 31/90 10 11
Montrose	Henderson, NV	32	70	36 03 32/114 58 34
PPG[b]	New Martinsville, WV	79	172	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	69	150	39 33 54/75 38 47
Total		355	772	

[a] See refs. 1, 2, and 3.

[b] Total production was distributed per site based on site capacity.

Table 7-2. o-Dichlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	12	30	43 35 28/84 13 08
Monsanto	Sauget, IL	6	16	38 35 31/90 10 11
PPG	New Martinsville, WV	15	38	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	19	50	39 33 54/75 38 47
Specialty Organics[c]	Irwindale, CA	1	2	34 06 30/117 55 48
Montrose	Henderson, NV	3	7	36 03 32/114 58 34
ICC	Niagara Falls, NY	3	8	43 03 33/79 00 55
Total		59	151	

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[a] See refs. 3, 4, and 5.

[b] Total production was distributed per site based on capacity.

[c] Processes dichlorobenzenes from Montrose.

Table 7-3. p-Dichlorobenzene Producers[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	9	30	43 35 28/84 13 08
Monsanto	Sauget, IL	4	12	38 35 31/90 10 11
PPG	New Martinsville, WV	13	40	39 47 22/80 51 27
Standard Chlorine	Delaware City, DE	24	75	39 33 54/75 38 47
Specialty Organics[c]	Irwindale, CA	1	2	34 06 30/117 55 48
Montrose	Henderson, NV	2	7	36 03 32/114 58 34
ICC	Niagara Falls, NY	2	8	43 03 33/79 00 55
Total		55	174	

[a] See refs. 3, 4, and 6.

[b] Total production was distributed per site based on capacity.

[c] Processes dichlorobenzenes from Montrose.

Table 7-4. Chlorobenzenes End-Use Distribution 1978[a]

Source	Usage (million lb/yr)	Usage (%)
Monochlorobenzene	355	100
Pesticide/degreasing solvents	174	49
Nitrochlorobenzene	107	30
DDT	25	7
Miscellaneous, others	49	14
o-Dichlorobenzene	59	100
3,4 dichloroaniline	38	65
Toluene diisocyanate solvent	9	15
Miscellaneous solvents (paint removers, engine cleaners, etc.)	6	10
Dye manufacturing	3	5
Pesticide intermediate	3	5
p-Dichlorobenzene	55	100
Space deodorant	27.5	50
Moth control	22	40
Pesticide intermediate	5.5	10

[a] See ref. 3.

of monochlorobenzene include DDT production. Approximately 65% of the o-dichlorobenzene produced is used for dichloroaniline manufacture, which is then used as an intermediate in pesticide manufacture. Other uses include solvents, dyes, and as a pesticide intermediate. Approximately 50% of the p-dichlorobenzene is used in the manufacture of space odorants and 40% is used in moth control. Pesticide manufacture, as a chemical intermediate, accounts for 10% of the p-dichlorobenzene usage.

Specific identified source locations of monochlorobenzene users are shown in Table 7-5.[7] They include nitrochlorobenzene, and DDT producers. Monchlorobenzene usage was distributed based on the individual plant's production capacity.

Specific identified source locations of o-dichlorobenzene users are shown in Tables 7-6 and 7-7. They include TDI production sites where o-dichlorobenzene is used as a solvent (Table 7-6[7]) and dichloroaniline sites where it is used as an intermediate (Table 7-7[7]). Total o-dichlorobenzene usage was distributed over the TDI sites based on TDI site capacity.

o-Dichlorobenzene usage for dichloroaniline manufacture was divided evenly over the four sites in the absence of capacity figures.

All other uses of chlorobenzenes are presented by a geographic region distribution in the emissions Section II of this report.

II. EMISSION ESTIMATES

A. PRODUCTION

Table 7-8 shows the monochlorobenzene emissions from production sites. Total estimated emissions from the 6 sites were 1,136,000 lb in 1978. Emission factors used to develop process, storage, and fugitive emission estimates are shown in Table 7-8. Process vent emissions originate primarily from distillation processes. Storage emissions represent losses from both working and final product storage tanks as well as loading and unloading losses. The number of tanks at a facility

Table 7-5. Monochlorobenzene End-Users[a]

Company	Location	End-Use Capacity (million lb/yr)	Monochlorobenzene Used (million lb/yr)	Geographic Coordinates Latitude/Longitude
		Nitrochlorobenzene Producers		
Du Pont	Deepwater, NJ	45	34	39 41 25/75 30 35
Monsanto	Sauget, IL	90	73	38 35 31/90 10 11
Total		140	107	
		DDT Producer		
Montrose	Torrance, CA	60	25	33 46 58/118 22 06

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[a] See ref. 7.

Table 7-6. o-Dichlorobenzene Solvent Users[a]
[Manufacturers of Toluene Diisocyanate (TDI)]

Company	Location	1978 TDI Capacity (10^6 lb/yr)	1978 o-Dichlorobenzene Use[b] (lb/yr)	Geographic Location Latitude/Longitude
Allied Chemical	Moundsville, WV	80	894,410	39 54 39/80 44 49
BASF Wyandotte	Geismar. LA	100	1,118,010	30 11 34/91 00 42
Dow Chemical	Freeport, TX	100	1,118,010	28 59 12/95 24 05
Du Pont	Deepwater, NJ	70	782,610	39 41 25/75 30 35
Mobay Chem. Corp.	Baytown, TX	130	1,453,416	29 45 30/94 54 25
	New Martinsville, WV	100	1,118,010	39 44 50/80 50 50
Olin Corp.	Ashtabula, OH	30	335,405	41 53 07/80 45 50
	Lake Charles, LA	100	1,118,010	30 13 55/93 15 57
Rubicon Chems. Inc.	Geismar, LA	40	447,205	30 12 00/91 11 30
Union Carbide	S. Charleston, WV	55	614,905	38 19 35/81 40 29
Total		805	9,000,000	

[a] See ref. 7.

[b] Total o-dichlorobenzene use is distributed per site based on TDI capacity.

Table 7-7. o-Dichlorobenzene Chemical Intermediate User Locations*

Source	Location	Geographic Coordinates (latitude/longitude)
2,4-Dichloroaniline Eastman Kodak Company	Rochester, NY	43 12 01/77 37 58
2,4-Dichloroaniline Blue Spruce Company	Bound Brook, NJ	40 32 10/74 29 18
Du Pont	Deepwater, NY	39 41 25/75 30 35
Monsanto	Luling, LA	29 55 10/90 22 30

*See ref. 7.

Table 7-8. Monochlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr)			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
Dow	Midland, MI	208,060	45,450	69,690	323,200	4.65
ICC	Niagara Falls, NY	10,300	2,250	3,450	16,000	0.23
Monsanto	Sauget, IL	142,140	31,050	47,610	220,800	3.18
Montrose	Henderson, NV	65,920	14,400	22,080	102,400	1.47
PPG	New Martinsville, WV	162,740	35,550	54,510	252,800	3.64
Standard Chlorine	Delaware City, DE	142,140	31,050	47,610	220,800	3.18
Total		731,300	159,750	244,950	1,136,000	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process	0.00206	A - [illegible]	(derived from site visit data)
Storage	0.00045	A -,	(derived from site visit data)
Fugitive	0.00069	A -[illegible]	(derived from site visit data)
Total	0.00320		

[b] Based on 8760 hr/yr operation.

are a function of the production and tank sizes. Fugitive emissions are those that result from plant equipment leaks. Emission estimates are based on a plant operation schedule of 24 hr/day, 7 days/week, 52 weeks/yr.

Table 7-9 shows the o-dichlorobenzene emissions from production sites. Total estimated emissions from the 7 sites were 209,450 lb in 1978. Emission factors used to develop the process, storage, and fugitive emissions are shown in Table 9.

Table 7-10 shows the p-dichlorobenzene emissions from production sites. Total estimated emissions from the 8 sites were 398,200 lb in 1978. Emission factors used to develop the process, storage, and fugitive emissions are shown in Table 7-10.

B. USES

1. Monochlorobenzene

It was estimated that 75% of the chlorobenzene used as solvent was consumed in cold cleaning operations. Total emissions of 130,500,000 lb were derived by assuming that all chlorobenzene consumed was lost. The total number of cleaners in service and the average emission rate per unit are shown in Table 7-11. Distribution of the cold cleaners by geographic region is shown in Table 7-12.

The remaining chlorobenzene was used as a solvent in pesticide manufacture. The entire amount used (43,500,000 lb) was assumed to be lost. The total emissions that are shown in Table 7-13 by geographic region were distributed by the number of sites in each region.

Emissions from chlorobenzenes used as chemical intermediates are summarized in Table 7-14. They were derived from the emission factors shown in Table 7-15, except where noted. Emissions from nitrochlorobenzene and DDT production were estimated to be 171,200 lb and 12,500 lb, respectively.

Miscellaneous uses of chlorobenzene were estimated by using an average emission factor derived for all other chlorobenzene uses of 0.00133 lb lost/lb used times the usage. Emissions from miscellaneous uses were estimated to have been 65,170 Source locations could not be identified for regional distribution.

Table 7-9. o-Dichlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Dow	Midland, MI	27,840	5,640	9,120	42,600	0.61
Monsanto	Sauget, IL	13,920	2,820	4,560	21,300	0.31
PPG	New Martinsville, WV	34,800	7,050	11,400	53,250	0.77
Standard Chlorine	Delaware City, DE	44,080	8,930	14,440	67,450	0.97
Specialty Organics	Irwindale, CA	2,320	470	760	3,550	0.05
Montrose	Henderson, NV	6,960	1,410	2,280	10,650	0.15
ICC	Niagara Falls, NY	6,960	1,410	2,280	10,650	0.15
Total		136,880	27,730	44,840	209,450	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process 0.00232 A - (derived from site visit data)
Storage 0.00047 A - (derived from site visit data)
Fugitive 0.00076 A - (derived from site visit data)
Total 0.00355

[b] Based on 8760 hr/yr operation.

Table 7-10. p-Dichlorobenzene Emissions from Production Sites

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Dow	Midland, MI	52,290	3,690	9,180	65,160	0.94
Monsanto	Sauget, IL	23,240	1,640	4,080	28,960	0.42
PPG	New Martinsville, WV	75,530	5,330	13,260	94,120	1.35
Standard Chlorine	Delaware City, DE	139,440	9,840	24,480	173,760	2.50
Specialty Organics	Irwindale, CA	5,810	410	1,020	7,240	0.10
Montrose	Henderson, NV	11,620	820	2,040	14,480	0.21
ICC	Niagara Falls, NY	11,620	820	2,040	14,480	0.21
Total		319,550	22,550	56,100	398,200	

[a] Based on the following emission factors (lb emitted per lb produced). See ref. 8.

Process	0.00581	A -	(derived from site visit data)
Storage	0.00041	A -	(derived from site visit data)
Fugitive	0.00102	A -	(derived from site visit data)
Total	0.00724		

[b] Based on 8760 hr/yr operation.

Table 7-11. Chlorobenzene Emissions from Solvent Degreasers[a]

Type Degreaser	Estimated National Emission (M lb/yr)[b]	Estimated Number of Units in Service	Average Emission Rate per Unit (lb/yr)	Average Emission Rate per Unit (g/sec)[c]
Cold cleaners	130.5	197,428	661	0.04

[a] See refs. 3 and 9.

[b] Assumes all chlorobenzene used in cold cleaners is lost.

[c] Based on 2250 hr/yr operation.

Table 7-12. Estimated Number of Degreasers Using Chlorobenzene in 1978 by Geographic Location*

Degreaser Type	North East	Mid Atlantic	East North Central	West North Central	South Atlantic	East South Central	West South Central	Mountain	Pacific	Total
Cold cleaners	11,869	30,780	52,272	17,309	23,817	11,678	19,166	7,164	23,374	197,428

*See ref. 10.

Table 7-13. 1978 Chlorobenzene Emission Estimates from Pesticide Manufacturers[a]

Region	Number of Sites per Region	Monochlorobenzene Emissions as Solvent (lb/yr)[b]	o-Dichlorobenzene Emissions (lb/yr)[c]	p-Dichlorobenzene Emissions (lb/yr)[d]
New England	4	1,251,800	43	80
Middle Atlantic	37	11,579,135	400	730
East North Central	19	5,946,045	205	375
West North Central	15	4,694,245	160	295
South Atlantic	17	5,320,145	185	335
East South Central	14	4,381,295	150	275
West South Central	15	4,694,245	160	295
Mountain	5	1,564,750	55	100
Pacific	13	4,068,345	140	255
Total	139	43,500,000	1500	2750

[a] See ref. 10.

[b] Average per site 312,950 lb/yr (4.51 g/sec).

[c] Average per site 10.8 lb/yr (0.0002 g/sec).

[d] Average per site 19.8 lb/yr (0.0003 g/sec).

Table 7-14. Emissions from Chlorobenzene End-Users (Chemical Intermediate)

		Emissions[a]				
		Process (lb/yr)	Storage (lb/yr)	Fugitive (lb/yr)	Total	
Company	Location				lb/yr	g/sec[b]
Monochlorobenzene						
Du Pont	Deepwater, NJ	37,400	6,800	10,200	54,400	0.78
Monsanto	Sauget, IL	80,300	14,600	21,900	116,800	1.68
Montrose	Torrance, CA	10,000	1,250	1,250	12,500	0.18
o-Dichlorobenzene						
Eastman	Rochester, NY	9,975	1,425	2,850	14,250	0.21
Blue Spruce	Bound Brook, NJ	9,975	1,425	2,850	14,250	0.21
Du Pont	Deepwater, NY	9,975	1,425	2,850	14,250	0.21
Monsanto	Luling, LA	1,400	200	400	2,000[c]	0.03

[a] Based on emission factors shown in table.

[b] Based on 8760 hr/yr operation.

[c] Based on Monsanto estimate using material balance calculations and sampling.

Table 7-15. Chlorobenzenes End-User Emission Factors

End-User	Emission Factor (lb lost/lb used)				Derivation[a]
	Process	Storage	Fugitive	Total	
Monochlorobenzene					
DDT	0.0004	0.00005	0.00005	0.00050	C[b]
Nitrochlorobenzene	0.0011	0.00020	0.00030	0.00160	C[b]
o-Dichlorobenzene					
4-Dichloroaniline	0.00105	0.00015	0.00030	0.00150	C[b]
Dye manufacturing	0.0004	0.00005	0.00005	0.0005	D
Pesticide intermed.	0.0004	0.00005	0.00005	0.0005	D
p-Dichlorobenzene					
Pesticide intermed.	0.0004	0.00005	0.00005	0.0005	D

[a] A - Basis: site visit data
B - Basis: published data
C - Basis: Hydroscience estimate

[b] See ref. 11

2. o-Dichlorobenzene

Emissions resulting from the use of o-dichlorobenzene as a solvent in TDI manufacture were estimated to be 5,259,164 lb by assuming that all usage is lost, except as noted. Table 7-16 summarizes TDI o-dichlorobenzene emissions which were distributed based on TDI capacity.

Emissions from chemical intermediate use of o-dichlorobenzene are shown in Table 7-14 for dichloroaniline manufacture (44,750 lb). Total emissions were distributed evenly per site, except where noted, since capacity data were not available. Emission factors used to derive o-dichlorobenzene emissions(except for the Monsanto source) are shown in Table 7-15.

Pesticide intermediate uses of o-dichlorobenzene were estimated to have been 1500 lb and were distributed by region in Table 7-13. Dye manufacturing losses were also estimated to be 1500 lb, but locations by region could not be identified.

Miscellaneous solvents primarily consumer types, (i.e., paint cleaners, engine cleaners, etc.) contributed 6,000,000 lb of o-dichlorobenzene emissions. Losses were considered too widespread to model.

p-Dichlorobenzene emissions from its use as a space deodorant were estimated as 27,500,000 lb and as 22,000,000 lb for moth control by assuming that total usage is lost. Losses were considered too widespread to model.

Emissions from p-dichlorobenzene used as a chemical intermediate in pesticide manufacture (2,750 lb) are shown in Table 13 by geographic region. Emissions were derived from the emission factors shown in Table 7-15 and distributed by the number of sites in each region.

Vent parameter data for producers and users of chlorobenzenes are shown in Table 7-17.

Total emissions of all three chlorobenzenes are summarized in Table 7-18. Total nationwide emissions of chlorobenzene, o-dichlorobenzene, and p-dichlorobenzene were 175,384,870 lb, 11,516,364 lb, and 49,900,950 lb respectively in 1978. Total emissions of all chlorobenzenes were established to have been 236,802,180 lb.

Table 7-16. o-Dichlorobenzene Emissions from Solvent Use in TDI Production

Company	Location	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied Chemical[c]	Moundsville, WV	4,508	0.06
Dow	Freeport, TX	1,118,010	16.10
DuPont	Deepwater, NJ	782,610	11.27
Mobay	Baytown, TX	1,453,416	20.92
	New Martinsville, WV	1,118,010	16.10
Olin	Ashtabula, OH	335,405	4.83
Rubicon	Geismar, LA	447,205	6.44
Total[d]		5,259,164	

[a] Based on total o-dichlorobenzene used as solvent lost as process emission.
[b] Based on 8760 hr/yr operation.
[c] See ref 13.
[d] Certain facilities in Table 7-6, claim zero emissions of o-Dichlorobenzene (ref 14, 15, 16

Table 7-17. Chlorobenzenes Vent Parameters[a]

		Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temp. (°F)	Velocity (ft/sec)	Distribution Area (ft x ft)
Production							
Process	m,o,p	3	60	0.125	104	20	
	p	5	30	0.80	120	12	
Storage	m	5	36	0.33	80		
	o	8	12	0.33	170		
	p	5	16	0.33	80		
Fugitive							300 x 600
Degreasing		1	15	0.5	70	0.6	
End-Uses[b]							
Process		1	20	0.17	140	12	
Storage		2	20	0.17	80		
Fugitive							100 x 100
Pesticide/DDT							
Process		1	30	0.17	100	15	
Storage		2	20	0.17	80		
Fugitive							300 x 300
TDI							
Process		1	90	0.9	110	40	

[a] Building cross-section Production - $50m^2$
Degreasing - $50m^2$
End-uses - $100m^2$
Pesticide - $100m^2$
TDI - $200m^2$

[b] Includes dichloroaniline, nitro chlorobenzene

Table 7-18. 1978 Nationwide Emissions of Chlorobenzenes

Source	Nationwide Emissions (lb/yr)
Monochlorobenzene	
Production	1,136,000
Pesticide/degreasing solvents	174,000,000
Nitrochlorobenzene	171,200
DDT	12,500
Miscellaneous, other[a]	65,170
Sub-total	175,384,870
o-Dichlorobenzene	
Production	209,450
3,4-Dichloroaniline	44,750
Toluene diisocynnate solvent	5,259,164
Miscellaneous solvents	6,000,000
Dye manufacturing	1,500
Pesticide intermediate	1,500
Sub-total	11,516,364
p-Dichlorobenzene	
Production	398,200
Space deodorant	27,500,000
Moth control	22,000,000
Pesticide intermediate	2,750
Sub-total	49,900,950
Total - all chlorobenzenes	236,802,180

[a] Based on an emission factor of 0.00133 lb lost/lb used derived from weighted average of all other monochlorobenzene uses.

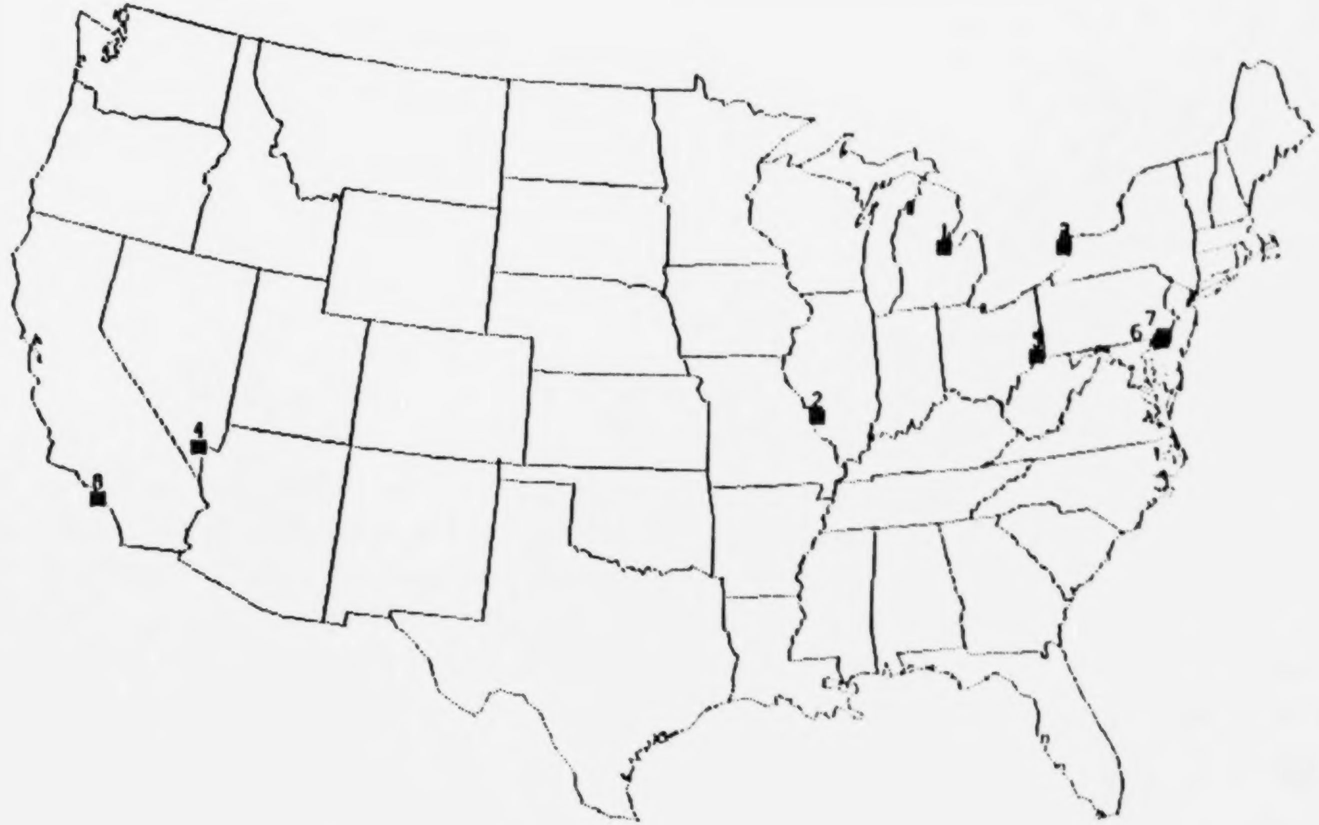

FIGURE 7-1. SPECIFIC POINT SOURCES OF CHLOROBENZENE(MONO) EMISSIONS

TABLE 7-19. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROBENZENE(MONO)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1	2.996064	.654480	1.003536
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	2	1 2	2.046816 1.156320	.447120 .210240	.685584 .315360
3	ICC	NIAGARA FALLS, NY	43 03 33	079 00 55	14747	3	1	.148320	.032400	.049680
4	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	5	1	.949248	.207360	.317952
5	PPG	NEW MARTINSVILLE, WV	39 47 22	080 51 27	13736	3	1	2.343456	.511920	.784944
6	STAND CHLORINE	DELAWARE CITY, DE	39 33 54	075 38 47	94741	3	1	2.046816	.447120	.685584
7	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	4	2	.538560	.097920	.146880
8	MONTROSE	TORRANC, CA	33 46 58	118 22 06	23129	5	3	.144000	.018000	.018000

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TABLE 7-19 (Concluded)

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* Plant Types:

Type 1: Plant produces chlorobenzene(mono)

Type 2: Plant produces chlorobenzene(mono) and nitro chlorobenzene

Type 3: Plant produces chlorobenzene(mono)

Type 4: Plant produces nitro chlorobenzene

Type 5: Plant produces DDT

† Source Types:

Type 1: Chlorobenzene(mono) production

Type 2: Nitro chlorobenzene production

Type 3: DDT production

TABLE 7-20. EXPOSURE AND DOSAGE OF CHLOROBENZENE(MONO) RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) . persons]
25	13	412
10	179	2,750
5	992	7,910
2.5	2,797	14,600
1	12,582	30,400
0.5	51,586	56,000
0.25	178,741	98,500
0.1	600,173	163,000
0.05	1,203,923	205,000
4.7×10^{-4}*	4,034,456	241,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 7-21. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF CHLOROBENZENE (MONO)

Concentration Level (μg/m^3)	Population Exposed (10^3 persons)			Dosage [10^6(μg/m^3) • persons]		
	Degreasing Operation	Pesticide Production	U.S. Total	Degreasing Operation	Pesticide Production	U.S. Total
100	0	2.2	2.2	0	0.30	0.30
50	0	14	14	0	1.10	1.10
25	0	56	56	0	2.54	2.54
10	0	215	215	0	4.84	4.84
5	0	485	485	0	6.70	6.70
2.5	0	1,490	1,490	0	10.1	10.1
1	0	4,250	4,250	0	14.2	14.2
0.5	0	9,030	9,030	0	17.7	17.7
0.25	--	--	--	0.94	21.8	22.7
0.1	--	--	--	5.23	27.3	32.5
0.05	--	--	--	9.40	31.9	41.3
0.025	--	--	--	14.0	35.3	49.3
0.01	--	--	--	21.5	36.4	57.8
0	--	--	--	104	36.4	141

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-22. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CHLOROBENZENE (MONO)

Parameter	Value
Daytime decay rate (K_d)	4.67×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.402 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-23. CHLOROBENZENE (MONO) EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Exposure Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
0.001000	505,140	1,081.9	0.	100.0	0.	100.0	0.	0.
0.000500	9,149,730	8,281.1	0.	100.0	0.	100.0	0.	0.
0.000250	27,819,254	14,972.1	0.	100.0	0.	100.0	0.	0.
0.000100	95,892,357	25,168.8	0.	100.0	0.	97.3	1.2	1.5
0.000050	140,093,202	28,469.2	0.	100.0	0.	94.2	2.5	3.3
0	158,679,135	29,091.4	0.	100.0	0.	92.9	2.6	4.5

TABLE 7-24. EXPOSURE AND DOSAGE SUMMARY OF CHLOROBENZENE (MONO)

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	0	2,200	0	2,200	0	300,000	0	300,000
50	0	14,000	0	14,008	0	1,100,000	0	1,100,000
25	13	56,000	0	56,013	412	2,540,000	0	2,540,412
10	179	215,000	0	215,179	2,750	4,840,000	0	4,842,750
5	992	485,000	0	485,992	7,910	6,700,000	0	6,707,910
2.5	2,797	1,490,000	0	1,492,797	14,600	10,100,000	0	10,114,600
1	12,582	--	0	--	30,400	14,200,000	0	14,230,400
0.5	51,586	--	0	--	56,000	17,700,000	0	17,756,000
0.25	178,741	--	0	--	98,500	22,700,000	0	22,798,000
0.1	600,173	--	0	--	163,000	32,500,000	0	32,663,000
0.05	1,203,932	--	0	--	205,000	41,300,000	0	41,505,000
0.025	--	--	0	--	--	49,300,000	0	--
0.01	--	--	0	--	--	57,800,000	0	--
0.001	--	--	505,140	--	--	--	1,082	--
0.0005	--	--	9,149,730	--	--	--	8,281	--
0.00025	--	--	27,819,254	--	--	--	14,972	--
0.0001	--	--	95,892,857	--	--	--	25,169	--
0.00005	--	--	140,098,202	--	--	--	28,469	
0	4,034,456	--	158,679,135	--	241,000	141,000,000	29,100	141,270,100

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

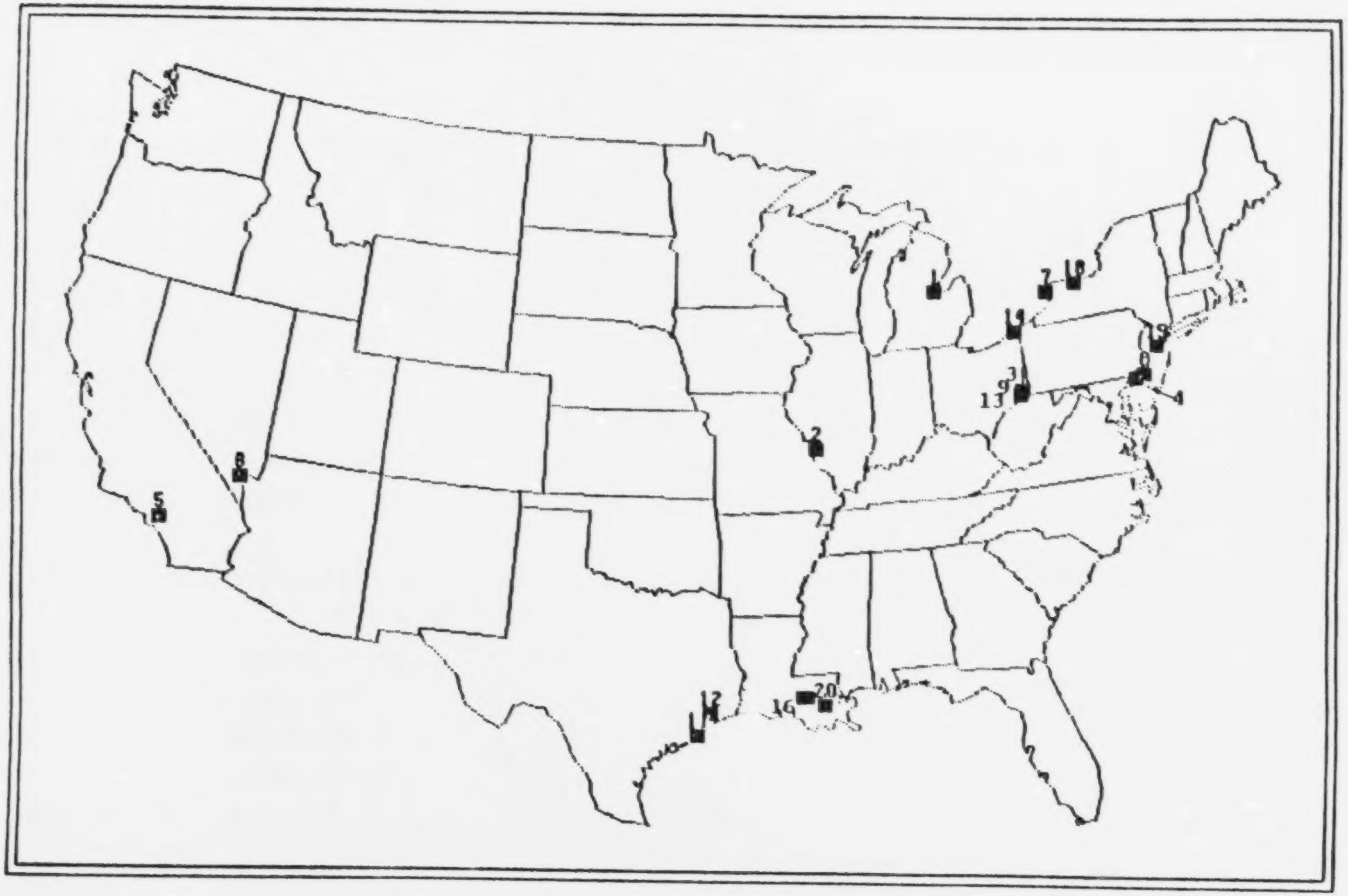
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FIGURE 7-2. SPECIFIC POINT SOURCES OF o-DICHLOROBENZENE EMISSIONS

Table 7-25. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF o-DICHLOROBENZENE

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1	.400875	.081176	.131342
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	1	1	.200439	.040592	.065671
3	PPG	NEW HARTINSVILLE, WV	39 47 22	080 51 27	13736	1	1	.501141	.101472	.164162
4	STAND CHLORINE	DELAWARE, CITY, DE	39 33 54	075 38 47	94741	1	1	.634704	.128616	.207921
5	SPECIALTY ORGAN	IRWINDALE, CA	34 06 30	117 55 48	23152	1	1	.033390	.006848	.010940
6	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	1	1	.100266	.020296	.032820
7	ICC	NIAGARA, NY	43 03 33	079 00 55	14747	1	1	.100266	.020296	.032820
8	DUPONT	DEEPWATER, NJ	39 41 25	075 15 50	13739	2	2	11.269596	0.	0.
							3	.143645	.020548	.041032
9	ALLIED	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	3	2	.064847	0.	0.
11	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	3	2	16.099346	0.	0.
12	MOBAY	BAYTOWN, TX	29 45 30	094 54 25	12906	3	2	20.099346	0.	0.
13	MOBAY	NEW MARTINSVILLE, WV	39 44 50	089 50 50	13736	3	2	16.099346	0.	0.
14	OLIN	ASHTABULA, OH	41 53 07	080 45 50	14843	3	2	4.829813	0.	0.
16	RUBICON	GEISMAR, LA	30 12 00	091 11 30	12958	3	2	6.437975	0.	0.
18	EASTMAN	ROCHESTER, NY	43 12 01	077 37 58	14771	4	3	.143645	.020548	.041032
19	BLUE SPRUCE	BOUND BROOK, NJ	40 32 10	074 29 18	14737	4	3	.143645	.020548	.041032
20	MONSANTO	LULING, LA	29 55 10	090 22 30	13958	4	3	.020161	.002884	.005759

[a] Some emission points have been eliminated due to comments to early drafts of this document.

TABLE 7-25 (Concluded)

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* Plant Types:

Type 1: Plant produces o-Dichlorobenzene
Type 2: Plant produces Toluene diisocyanate and 3,4-Dichloroaniline
Type 3: Plant produces Toluene diisocyanate
Type 4: Plant produces 3,4-Dichloroaniline

† Source Types:

Type 1: o-Dichlorobenzene production
Type 2: Toluene diisocyanate production
Type 3: 3,4-Dichloroaniline production

TABLE 7-26. EXPOSURE AND DOSAGE OF o-DICHLOROBENZENE FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) . persons]
50	6	373
25	36	1,380
10	350	5,330
5	1,294	10,120
2.5	5,569	25,600
1	39,571	76,000
0.5	95,918	116,000
0.25	154,256	137,000
0.1	385,422	175,000
0.05	578,509	189,000
0.025	757,868	195,000
0.01	1,444,164	206,000
7.17×10^{-5}*	6,052,014	219,000

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 7-27. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF o-DICHLOROBENZENE (PESTICIDE PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [$10^3(\mu g/m^3) \cdot$ persons]
0.01	0.8	0.009
0.005	7	0.05
0.0025	30	0.13
0.001	--	0.27
0.0005	--	0.40
0.00025	--	0.57
0	--	2.46

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-28. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF o-DICHLOROBENZENE

Parameter	Value
Daytime decay rate (K_d)	7.5×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-7} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	86.42 gm/sec
Dye production	0.02 gm/sec
Miscellaneous solvents	86.4 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-29. o-DICHLOROBENZENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.250000	505140	282451.4	0.	100.0	0.	100.0	0.	0.
.100000	9149780	1772052.3	0.	100.0	0.	100.0	0.	0.
.050000	33072205	3479775.2	0.	100.0	0.	100.0	0.	0.
.025000	81759648	5036401.0	0.	100.0	0.	100.0	0.	0.
.010000	142928535	6121131.0	0.	100.0	0.	98.0	.7	1.2
0.	158679135	6225594.7	0.	100.0	0.	94.0	2.5	3.5
						92.9	2.6	4.5

TABLE 7-30. EXPOSURE AND DOSAGE SUMMARY OF o-DICHLOROBENZENE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
50	6	0	0	6	373	0	0	373
25	36	0	0	36	1,380	0	0	1,380
10	350	0	0	350	5,330	0	0	5,330
5	1,294	0	0	1,294	11,200	0	0	11,200
2.5	5,569	0	0	5,569	25,600	0	0	25,600
1	39,571	0	0	39,571	76,000	0	0	76,000
0.5	95,918	0	0	95,918	116,000	0	0	116,000
0.25	154,256	0	505,140	659,396	137,000	0	232,451	369,451
0.1	385,422	0	9,149,730	9,535,152	175,000	0	1,772,052	1,947,052
0.05	578,509	0	33,072,205	33,650,714	189,000	0	3,479,775	3,668,775
0.025	757,868	0	81,759,648	82,517,516	195,000	0	5,056,481	5,251,481
0.01	1,444,164	800	142,928,535	144,373,490	206,000	9	6,121,131	6,327,131
0	6,052,014	--	158,679,135	--	219,000	2.460	6,225,594	6,447,054

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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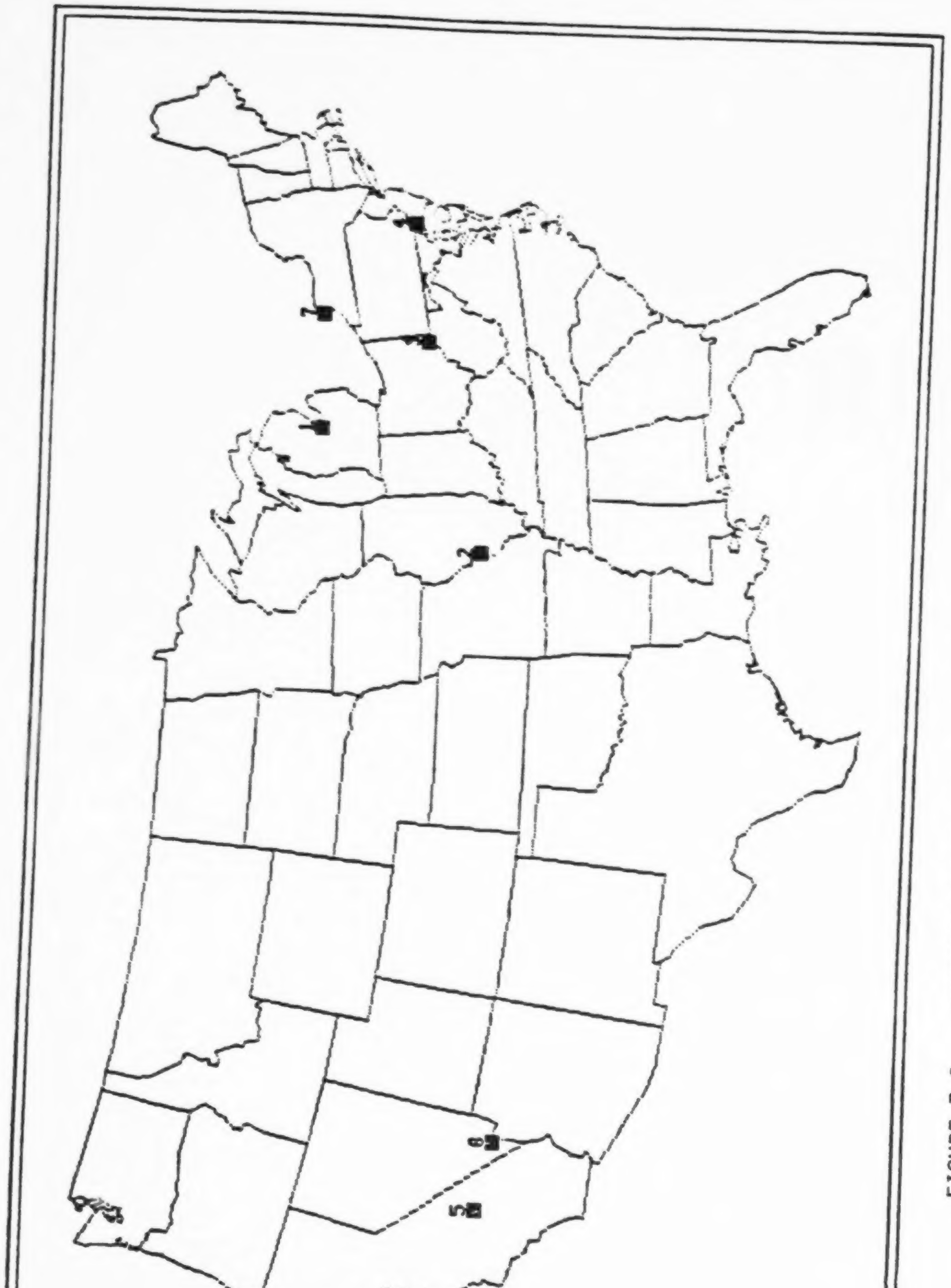

FIGURE 7-3. SPECIFIC POINT SOURCES OF p-DICHLOROBENZENE EMISSIONS

TABLE 7-31. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-DICHLOROBENZENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE	SOURCE TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1	.752976	.053136	.132192
2	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	1	1	.334656	.023616	.058752
3	PPG	NEW MARTINSVILLE,WV	39 47 22	080 51 27	13736	1	1	1.087632	.076752	.190944
4	STAND CHLORINE	DELEWARE CITY, DE	39 33 54	075 38 47	94741	1	1	2.007936	.141696	.352512
5	SPECIALTY ORGAN	IRWINDALE, CA	36 06 30	117 55 48	23215	1	1	.083664	.005904	.014688
6	MONTROSE	HENDERSON, NV	36 03 32	114 58 34	23112	1	1	.167328	.011808	.029376
7	ICC	NIAGARA FALLS, NY	43 03 33	079 00 55	14747	1	1	.167328	.011808	.029376

TABLE 7-32. EXPOSURE AND DOSAGE OF p-DICHLOROBENZENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (μg/m^3)	Population Exposed (persons)	Dosage [(μg/m^3) · persons]
50	2	118
25	8	328
10	42	815
5	127	1,420
2.5	389	2,350
1	1,691	4,330
0.5	3,879	5,930
0.25	10,792	8,400
0.1	36,631	12,200
0.05	126,422	18,400
0.025	384,501	27,400
0.01	888,210	35,200
0.00035	2,341,084	41,400

TABLE 7-33. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF p-DICHLOROBENZENE (PESTICIDE PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [$10^3(\mu g/m^3)$ • persons]
0.01	3.4	0.05
0.005	19.6	0.16
0.0025	59.6	0.30
0.001	--	0.55
0.00025	--	0.76
0	--	3.73

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* The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 7-34. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF p-DICHLOROBENZENE

Parameter	Value
Daytime decay rate (K_d)	7.5×10^{-6} sec^{-1}
Nighttime decay rate (K_n)	5.0×10^{-7} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	713 gm/sec
Space deodorant	396 gm/sec
Moth control	317 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 7-35. p-DICHLOROBENZENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
2.500000	505140	1917817.8	0.	100.0	0.	100.0	0.	0.
1.000000	9149730	14620149.2	0.	100.0	0.	100.0	0.	0.
.500000	26976292	26029910.4	0.	100.0	0.	100.0	0.	0.
.250000	61583693	37167988.3	0.	100.0	0.	100.0	0.	0.
.100000	133037356	49590816.2	0.	100.0	0.	98.3	.5	1.2
0.	150679135	51363670.0	0.	100.0	0.	94.7	2.4	2.9
						92.9	2.6	4.5

TABLE 7-36. EXPOSURE AND DOSAGE SUMMARY OF p-DICHLOROBENZENE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
50	2	0	0	2	118	0	0	118
25	8	0	0	8	328	0	0	328
10	42	0	0	42	815	0	0	815
5	127	0	0	127	1,420	0	0	1,420
2.5	389	0	505,140	505,529	2,350	0	1,917,818	1,920,168
1	1,691	0	9,149,730	9,151,421	4,330	0	14,620,149	14,624,479
0.5	3,879	0	26,976,292	26,980,171	5,930	0	26,029,918	26,035,848
0.25	10,792	0	61,583,693	61,594,485	8,400	0	37,167,988	37,176,388
0.1	36,631	0	--	--	12,200	0	49,590,816	49,603,016
0.05	126,422	0	--	--	18,400	0	--	--
0.025	384,501	0	--	--	27,400	0	--	--
0.01	888,210	3,400	--	--	35,200	50	--	--
0.005	--	19,600	--	--	--	160	--	--
0	2,341,084	--	158,679,135	--	41,400	3,360	51,363,678	51,408,438

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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2:B-29 & 30

APPENDIX A-8 ----- Chloroform

CHLOROFORM CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 67-66-3

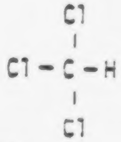
Synonyms: Trichloromethane; Methenyl Chloride; Trichloroform; Methenyl Trichloride; Formyl Trichloride; Methyl Trichloride

Chemical Formula

Molecular Weight: 119.39

Molecular Formula: $CHCl_3$

Molecular Structure:



$$\begin{array}{c} Cl \\ | \\ Cl-C-H \\ | \\ Cl \end{array}$$

Chemical and Physical Properties

Physical State at STP: Liquid - highly refractive, nonflammable, heavy, very volatile

Boiling Point: 61.25°C

Melting Point: -63.5°C

Density: 1.49845 at 15°C

Vapor Pressure: 200 mm at 25.9°C

Vapor Density: 4.12

Solubility: Soluble (8.15 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 1.17

Atmospheric Reactivity

Transformation Products: Easily hydrolyzed by aqueous alkali to formic acid. When exposed to air and light, breaks down to phosgene, HCl, and chlorine.
Reactivity Toward OH·: same as methane, 1/4% Butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: No photochemical degradation

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

Four volatile organic compounds——methyl chloride, methylene chloride, chloroform, and carbon tetrachloride——comprise the group of chemicals commonly referred to as the chloromethanes. Emission losses for all except methyl chloride are assessed in this summary.

CHLOROFORM

Chloroform ($CHCl_3$) is a clear, water-white, heavy, volatile, nonflammable liquid at ambient conditions and is manufactured by the chlorination of either methyl chloride or methane. The chlorination of methane is the predominant route for the manufacture of chloroform.

In 1978 five companies were operating plants at seven locations in the U.S. The locations of the plants, the type of production process used, and the 1978 capacity and estimated production level for each plant are shown in Table 8-1.[4,6,7] An estimated 330 million lb of chloroform was produced in 1978.

The largest end-use for chloroform is in the manufacture of chlorodifluoromethane, commonly referred to as fluorocarbon 22 or F-22. Fluorocarbon 22 is used primarily as a refrigerant with an estimated 61% of the chloroform production (201.3 million lb) consumed for this application. In addition an estimated 82.5 million lb of chloroform was consumed to produce fluorocarbon 22 that was subsequently used as a chemical intermediate to produce fluorocarbon resins.

The remaining 1978 chloroform production was either exported (23.1 million lb) or used as an industrial solvent to produce pharmaceuticals or pesticides (23.1 million lb). End-uses of chloroform are summarized in Table 8-2.[6]

For the purpose of this report emissions resulting from the export of chloroform are assumed to be negligible. The remaining chloroform produced (23.1 million lb) is used as a solvent in a variety of end-use applications and is eventually released to the atmosphere. Individual source locations could not be identified for this broad category. Estimated emissions losses for each producing location are shown in Table 8-3.

Total nationwide emissions of chloroform from all sources are estimated to be 23,820,000 lb. A tabulation of the losses is shown in Table 8-4.

The most significant end-use for chloroform is as a chemical intermediate in the production of fluorocarbon 22. Identified source locations for fluorocarbon 22 manufacture are shown in Table 8-5.[13] Also shown in that table are the 1973 fluorocarbon 22 production and the corresponding chloroform requirement for its manufacture.

Emission estimates of chlorofrom from these sites are shown in Table 8-6.[14] Total estimated emissions of chloroform from fluorocarbon 22 production sites are estimated to be 373,460 lb. Additional associated emissions from these sites would include other halocarbons used and the various fluorocarbons produced. Vent parameter data relative to chloroform emissions from fluorocarbon production are shown in Table 8-7. It is estimated that an average of five tanks per site contribute chloroform storage emissions. Process emissions were reported as negligible.[14]

Table 8-1. Production of Chloroform[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	Process[c]	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical Corp.	Moundsville, WV	19	A,B[d]	30	39 54 24/80 47 51
Diamond Shamrock	Belle, WV	26	A	40	38 14 09/81 32 38
Dow Chemical	Freeport, TX	64	B	100	28 59 15/45 24 45
	Plaquemine, LA	64	A	100	30 19 00/91 15 00
Stauffer Chemical Co.	Louisville, KY	49	A	75	38 12 09/85 51 49
Vulcan Materials Co.	Geismar, LA	38	A	60	30 10 00/90 59 00
	Wichita, KS	70	A,B[e]	110	37 36 55/97 18 30
Total		330		515	

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[a] See refs. 4, 6, and 7.

[b] Distribution of the 330 million pounds per year for each producing location has been made as a direct ratio of total production/total capacity X individual plant capacity.

[c] (A) - Methanol hydrochlorination process or methyl chloride chlorination process.
(B) - Methane chlorination process.

[d] 5% methane chlorination 95% methyl chloride chlorination.

[e] 10% methane chlorination 90 % methyl chloride chlorination.

Table 8-2. 1978 Chloroform Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption (M lb)
Chlorodifluoromethane (F-22) refrigerants	61	201.3
Chlorodifluoromethane (F-22) resin intermediates	25	82.5
Export	7	23.1
Solvent/miscellaneous	7	23.1
Total	100	330.0

*See refs. 6 and 7.

Table 8-3. 1978 Chloroform Production Emissions

Company	Location	Process Vent Emissions (lb/yr)	Process Vent Emissions (g/sec)[b]	Storage Vent Emissions (lb/yr)	Storage Vent Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied Chemical	Moundsville, WV	140	0.002	17,870	0.257	4,630	0.067	22,640	0.326
Diamond Shamrock	Belle, WV	200	0.003	25,350	0.365	6,420	0.092	31,970	0.460
Dow Chemical	Freeport, TX	260	0.004	18,470	0.266	11,500	0.166	30,230	0.435
	Plaquemine, LA	480	0.007	62,400	0.898	15,810	0.228	78,690	1.133
Stauffer	Louisville, KY	370	0.005	47,780	0.688	12,100	0.174	60,250	0.867
Vulcan	Geismar, LA	290	0.004	37,050	0.533	9,390	0.135	46,730	0.673
	Wichita, KA	500	0.007	63,450	0.913	16,820	0.242	80,770	1.163
Total		2,240		272,370		76,670		351,280	

[a] Derived from the emission factors shown in Table 10.

[b] Based on 8760 hr/yr operation.

Table 8-4. Estimated Chloroform Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	0.35
Chlorodifluoromethane (F-22) (refrigerants)	0.37
Chlorodifluoromethane (F-22) resin intermediates	
Solvent, miscellaneous	23.1
Export	0
Total	23.82

Table 8-5. Users of Carbon Tetrachloride and Chloroform to Produce Fluorocarbons

	Flurorocarbon Annual Capacity (10^6 lb)	Estimated 1978 Production F-11 (10^6 lb)	Estimated 1978 Production F-12 (10^6 lb)	Estimated 1978 Production F-22 (10^6 lb)	Estimated Production Totals (10^6 lb)	Carbon Tetra-chloride Used (10^6 lb)	Chloro-form Used (10^6 lb)	Geographic Coordinates Latitude/Longitude
Allied Chemical								
Baton Rouge, LA		Assumed shut down						
Danville, IL	310	28.5	40.6			87.3		40 08 30/87 33 45
Elizabeth, NJ		28.5	40.6	37.8	282.9	87.3	55.7	40 40 45/74 13 51
El Segundo, CA		28.5	40.6	37.8		87.3	55.7	33 56 30/118 26 35
Du Pont								
Antioch, CA		36.8	52.3			112.6		37 59 37/121 52 00
Deepwater, NJ		36.8	52.3	48.8		112.6	71.9	39 41 25/75 30 35
Montague, MI	400	36.8	52.3		364.9	112.6		43 24 10/86 23 40
Louisville, KY				48.8			71.9	38 11 51/85 54 13
Corpus Christi, TX								27 53 00/97 15 00
Pennwalt Corp.								
Calvert City, KY	80	22.1	31.4	19.5	73.0	67.6	28.6	37 03 18/88 19 40
Thorofare, NJ	35	Assumed shutdown						
Union Carbide								
Institute and S. Charleston, WV	Not listed	Assumed shutdown						
Essex Chemical Corp. (Racon)								
Wichita, KS	20							
Kaiser Aluminum & Chemical Corp.								
Gramercy, LA	80							
Total	925	218	310.1	192.7	720.8	667.5	283.8	

*See ref. 13.

Table 8-6. Emissions from Carbon Tetrachloride and Chloroform Users for Flurocarbon Production[a]

Source	Location	F-11/F-12 Carbon Tetrachloride Emissions (lb/yr)[b]	F-11/F-12 Carbon Tetrachloride Emissions (g/sec)[d]	F-22 Chloroform Emissions (lb/yr)[c]	F-22 Chloroform Emissions (g/sec)[d]
Allied[e]	Danville, IL	58,460	0.84	0	
	Elizabeth, NJ	0	0	16,350	0.24
	El Segundo, CA	3,400	0.05	100	0.001
Du Pont	Antioch, CA	75,420	1.09	0	0
	Deepwater, NJ	75,420	1.09	148,800	2.14
	Montague, MI	75,420	1.09	0	0
	Louisville, KY	0		148,800	2.14
Pennwalt	Calvert City, KY	45,240	0.65	59,410	0.86
Total		333,360		373,460	

[a] See ref. 14.

[b] Based on the following emission factor, except where noted

Process	0.000449	A - (derived from site visit)
Storage	0.000442	A - (derived from site visit)
Fugitive	0.000178	A - (derived from site visit)
	0.001069	

[c] Based on the following emission factor, except where noted

Process	0	A - (derived from site visit)
Storage	0.00374	A - (derived from site visit)
Fugitive	0.00075	A - (derived from site visit)
	0.00449	

[d] Assumes 8760 hours/year operation.

[e] Allied Company has supplied their own emissions estimates.[15]

Table 8-7. Chloromethane Vent Parameters[a]

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
tion[b]					
l chloride chlo- ation					
Process	3	35	0.08	95	5.0
Storage	10	20	0.17	80	
ane chlorination					
Process	2	35	0.08	100	270
Storage	10	20	0.17	80	
on disulfide and er chlorination ocesses					
Process	2	45	0.17	100	9.0
Storage	7	20	0.17	80	
ene chloride end-use[c]					
Cold cleaner	1	15	0.5	70	0.6
Vapor degreaser	1	15	0.5	150	
carbons 11/12[d]					
Process	2	30	0.33	90	
Storage	4	20	0.17	80	
carbon 22[d]					
Process[e]	0	0	0	0	0
Storage	2	20	0.17	80	

efs. 1, 2, 10, and 14.

ng cross-section - 5 m^2

ng cross-section - 50 m^2

ng cross-section - 20 m^2

are no process vent losses of chloroform from f-22 manufacture.

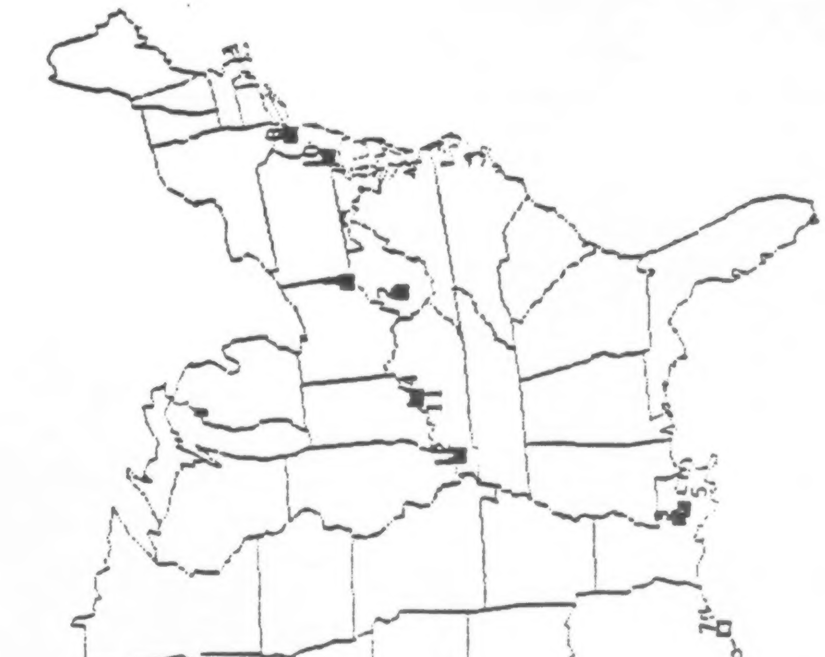

FIGURE 8-1. SPECIFIC POINT SOURCES OF CHLOROFORM EMISSIONS

TABLE 8-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROFORM

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	1	1	.002016	.257328	.066672
2	DIAMND SHAMROCK	BELLE, WV	38 14 09	081 32 38	13866	1	1	.002880	.365040	.092448
3	DOW	PLAQUEMINE, LA	30 19 00	091 15 00	13970	1	1	.006912	.090560	.227664
4	STAUFFER	LOUISVILLE, KY	38 12 09	085 51 49	93820	1	1	.003328	.680032	.174240
5	VULCAN	GEISMAR, LA	30 10 00	090 59 00	12958	1	1	.004176	.533520	.135216
6	VULCAN	WICHITA, KA	37 36 33	097 18 30	03928	1	1	.007200	.913680	.242208
7	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	2	2	.003744	.268960	.166608
8	ALLIED	ELIZABETH, NT	40 40 45	074 13 51	04739	3	3	0	.228695	.006473
9	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129	3	3	0.	0.	.001438
10	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	3	3	0.	1.704736	.357984
11	DUPONT	LOUISVILLE, KY	38 11 51	085 54 13	13807	3	3	0.	1.704736	.357984
12	PENNWALT	CALVERT CITY, KY	37 03 10	088 19 40	03816	3	3	0.	.712000	.142560

TABLE 8-9. (Concluded)

---

* Plant Type:

Type 1: Plant produces chloroform by using the methylchloride chlorination process

Type 2: Plant produces chloroform by using the methan chlorination process

Type 3: Plant produces flurocarbon 22

† Source Type:

Type 1: Methyl chloride chlorination process

Type 2: Methane chlorination process

Type 3: Flurocarbon 22 production

TABLE 8-10. EXPOSURE AND DOSAGE OF CHLOROFORM RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
25	9	281
10	81	1,330
5	301	2,830
2.5	921	4,960
1	8,387	19,800
0.5	28,456	34,500
0.25	52,915	42,900
0.1	220,934	68,600
0.05	728,929	104,000
0.025	1,619,506	136,000
0.01	2,762,466	154,000
0.005	3,922,379	162,000
4.21×10^{-6}*	7,619,827	168,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 8-11. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF CHLOROFORM

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	332.6 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 8-12. CHLOROFORM EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
1.000000	505140	895925.3	0.	100.0	0.	100.0	0.	0.
.500000	9149720	6895977.5	0.	100.0	0.	100.0	0.	0.
.250000	21839363	11010193.3	0.	100.0	0.	100.0	0.	0.
.100000	78609357	19384869.4	0.	100.0	0.	98.1	.7	1.2
.050000	129499835	23221696.1	0.	100.0	0.	95.2	2.3	2.5
0.	158679135	24223708.2	0.	100.0	0.	92.9	2.6	4.5

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TABLE 8-13. EXPOSURE AND DOSAGE SUMMARY OF CHLOROFORM

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
25	9	0	0	9	281			218
10	81	0	0	81	1,330	0	0	1,330
5	301	0	0	301	2,830	0	0	2,830
2.5	921	0	0	921	4,960	0	0	4,960
1	8,387	0	505,140	513,527	19,800	0	895,925	915,725
0.5	28,456	0	9,149,730	--	34,500	0	6,895,977	6,930,477
0.25	52,915	0	21,839,303	--	42,900	0	11,010,193	11,053,093
0.1	220,934	0	78,609,557	--	68,600	0	19,384,869	19,453,469
0.05	728,929	0	129,499,835	--	104,000	0	23,221,696	23,325,695
0.025	1,619,506	0	--	--	136,000	0	--	--
0.01	--	0	--	--	154,000	0	--	--
0.005	--	0	--	--	--	0	--	--
0	7,619,827	0	158,679,135	--	168,000	0	24,223,708	24,391,708

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-9 ----- Chloroprene

CHLOROPRENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 126-99-8

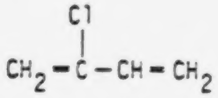
Synonyms: 2-Chlorobutadiene-1,3; β-Chloroprene; Chloroprene;
2-Chloro-1,3-Butadiene

Chemical Formula

Molecular Weight: 88.54

Molecular Formula: C_4H_5Cl,

Molecular Structure:



$$CH_2 = \overset{\overset{\displaystyle Cl}{|}}{C} - CH = CH_2$$

Chemical and Physical Properties

Physical State at STP: Liquid-colorless, flammable, pungent ethereal odor

Boiling Point: 59.4°C at 760 mm

Melting Point:

Density: 0.9583 at 20°C/4°C

Vapor Pressure: 215.4 mm at 25°C

Vapor Density: 3.0

Solubility: Slightly soluble (<10.0 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: 2-Chloroacrolein, Chloroacrolein

Reactivity Toward OH·: 4 x Butane

Reactivity Toward O_3: 2 x Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors:

Formation Reactivity:

I. SOURCES

Chloroprene is currently produced in the United States by chlorination, isomerization, and caustic dehydrochlorination from butadiene. Until the late 1960s, chloroprene was also produced from acetylene, but that process has been discontinued because the cost of acetylene is much higher than that of butadiene.

Only two companies at three locations currently produce chloroprene in the United States. Dupont shut down its Louisville, KY, chloroprene facility and expanded its Laplace, LA, facility. Dupont's Victoria, TX, facility has also begun production of chloroprene. The locations of the plants and the 1978 capacity and estimated production for each site are shown in Table 9-1. An estimated 277.2 million lb of chloroprene was produced in 1978.[1,2]

All chloroprene produced is captively consumed to manufacture polychloroprene (neoprene) synthetic rubber by polymerization of the chloroprene. Neoprene is used in wire and cable covers, gaskets, automobile parts, caulks, and other applications requiring chemical, oil, and weather resistance.

II. EMISSION ESTIMATES

Emission estimates for the three sites listed in Table 9-1 include the total emissions of chloroprene, and toluene from the Dupont sites, for both the production of chloroprene and its captive use to make neoprene.

Emission factors used to calculate the emissions of chloroprene and toluene are shown in Table 9-2, along with vent parameter data.

Total emissions of chloroprene from its production and use are estimated to have been 3,523,090 lb, and those of toluene are estimated to have been 895,433 lb. There were no identified toluene emissions associated with chloroprene or neoprene manufacture at the Denka facility. Total emissions are shown in Table 9-3 by site location.

Table 9-1. Chloroprene Producers and Captive Users[a]

Company	Location	1978 Capacity (M lb)	1978 Production (M lb)[b]	Geographic Coordinates Latitude/Longitude
Du Pont	Laplace, LA	190	169.4	30 04 00/90 32 00
	Victoria, TX[c]	60	53.9	28 40 29/96 57 21
Denka	Houston, TX	60	53.9	29 41 31/95 15 12
Total		310	277.2	

[a] See refs. 1 and 2.

[b] Total production distributed over all sites based on capacity.

[c] Total capacity and estimated production have been determined by the difference in overall U.S. capacity and overall U.S. demand for neoprene.

Table 9-2. Chloroprene/Toluene Emission Factors and Vent Parameter Data

Source	Chemical	Emission Factor lb Lost per lb Produced/Used Process	Storage	Fugitive	Total
		Emission Factors			
Du Pont sites	Chloroprene	0.014000[a]	0.000004[b]	0.001000[c]	0.015004
	Toluene	0.00347[a]	0.00004[a]	0.00050[c]	0.00401
Denka site	Chloroprene	0.002200[b]	0.000004[b]	0.001000[c]	0.003204

Vent Parameter Data

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Vent Discharge Temperature (°F)	Vent Velocity (ft/sec)	Discharge Area (ft X ft)
All sites[d]						
Process	6	56	1.25	100	85	
Storage	4	16	0.33	75		
Fugitive						400 X 600

[a] See ref. 3.

[b] See ref. 4.

[c] Hydroscience estimate.

[d] Building cross section all sites - 100 m^2.

Table 9-3. Chloroprene and Toluene Emissions from Chloroprene Production and Use

Company	Location	Emissions (lb/yr)[a]			Total Emissions[a]	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)[b]
		Chloroprene Emissions				
Du Pont	Laplace, LA	2,371,600	678	169,400	2,541,678	36.59
	Victoria, TX	754,600	216	53,900	808,716	11.64
Denka	Houston, TX	118,580	216	53,900	172,696	2.49
Total		3,244,780	1,110	277,200	3,523,090	
		Toluene Emissions				
Du Pont	Laplace, LA	587,818	6,776	84,700	679,294	9.78
	Victoria, TX	187,033	2,156	26,950	216,139	3.11
Total		774,851	8,932	111,650	895,433	

[a] Based on emission factors shown in Table 2.

[b] Based on 8760 hr/yr operation.

Process emissions originate from the chloroprene reactor vent scrubber, the neoprene strippers, and the neoprene dryer exhausts. Storage emissions represent the losses from both working and final product storage as well as loading and handling losses. Fugitive emissions as those that result from plant equipment leaks.

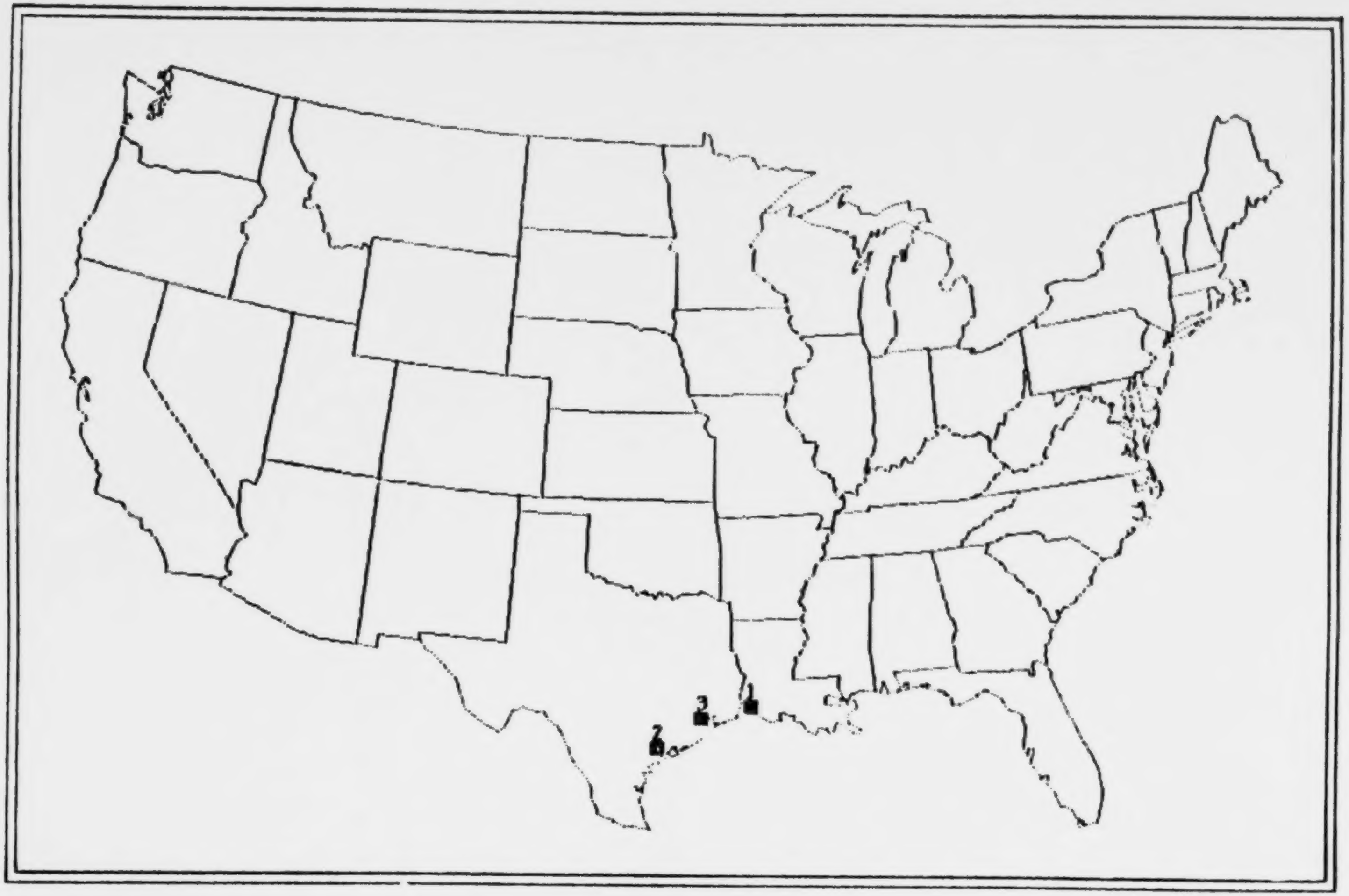


FIGURE 9-7: SPECIFIC POINT SOURCES OF CHLOROPRENE EMISSIONS

TABLE 9-4. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF CHLOROPRENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE	SOURCE TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	DUPONT	LAPLACE, LA	30 04 00	093 20 01	2950	1	1	34.151040	.009763	2.439360
2	DUPONT	VICTORIA, TX	28 40 29	096 57 21	12923	1	1	10.866240	.003110	.776160
3	DENKA	HOUSTON, TX	29 41 31	095 15 12	12906	1	1	1.707552	.003110	.776160

TABLE 9-5. EMISSIONS PARAMETERS FOR SPECIFIC POINT SOURCES OF CHLOROPRENE

Source Type '	Emissions Category	Vent Height (m)	Building Cross Section (m^2)	Vent Diameter (m)	Vent Velocity (m/sec)	Vent Temperature (°k)
	Process	17	100	0.38	26	311
	Storage	5	100	--	--	--
	Fugitive	0	100	--	--	--

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 9-6. EXPOSURE AND DOSAGE OF CHLOROPRENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
100	27	3,560
50	126	10,300
25	443	22,000
10	2,762	57,700
5	7,322	91,000
2.5	14,083	114,000
1	34,121	150,000
0.5	65,675	171,000
0.25	129,903	192,000
0.1	332,934	224,000
0.05	695,229	249,000
0.0047*	1,414,679	272,000

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* The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. Sara L. Soder, "Butadiene Marketing Research Report," Chemical Economics Handbook, Stanford Research Institute, June 1977.

2. Chemical Marketing Reporter, Chemical Profiles Neoprene, August 16, 1976.

3. D. D. Wild, Louisiana Air Control Commission, Emission Inventory Questionnaire for Dupont Chemical, March 3, 1977.

4. M. Z. Woskow, Texas Air Control Board Emissions Inventory Questionnaire for Petrotex Chemical, Aug. 26, 1976.

APPENDIX A-10 ----- Cresol

m-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-39-4

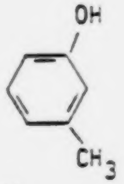
Synonyms: 3-Methylphenol; m-Hydroxyltoluene

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless or yellowish, phenolic odor

Boiling Point: 202.8°C

Melting Point: 12°C

Density: 1.034 at 20°C/4°C

Vapor Pressure: 1 mm at 52.0°C

Vapor Density: 3.72

Solubility: Slightly soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.37

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 12 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: Toluene

Formation Reactivity: Small formation pathway (<10% from all cresols) from toluene decay

o-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-48-7

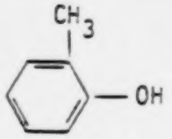
Synonyms: o-Cresylic Acid; o-Hydroxyltoluene; 2-Methylphenol

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid crystals - non volatile phenolic odor

Boiling Point: 190.8°C

Melting Point: 30.9°C

Density: 1.047 at 20°C/4°C

Vapor Pressure: 1 mm at 38.2°C

Vapor Density: 3.72

Solubility: Soluble (31 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.40

Atmospheric Reactivity

Transformation Products: Reacts with oxidizing materials to yield quinones and benzenes (<1 day in air, <10 days in water). Methyl quinone, methyldihydroxyl benzenes

Reactivity Toward OH·: 10 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis: N/A

Major Atmospheric Precursors: Toluene

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Formation Reactivity: See m-Cresol

p-CRESOL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 106-44-5

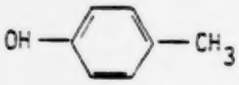
Synonyms: 4-Cresol; 4-Methylphenol; p-Hydroxyltoluene

Chemical Formula

Molecular Weight: 108.1

Molecular Formula: C_7H_8O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid crystals - phenolic odor

Boiling Point: 201.8°C

Melting Point: 35.26°C

Density: 1.0341 at 20°C/4°C

Vapor Pressure: 1 mm at 53.0°C

Vapor Density: 3.72

Solubility: Slightly soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.35

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 10 x Butane

Reactivity Toward O_3: 10% Propylene

Reactivity Toward Photolysis:

Major Atmospheric Precursors: Toluene

Formation Reactivity: See m-Cresol

I. SOURCES

A. PRODUCTION

The cresol isomers include para-cresol, ortho-cresol, and meta-cresol. Production and capacity information is normally expressed in terms of total cresols and cresylic acid rather than the individual cresol isomers. Cresols typically occur as mixture of the cresol isomers and are defined as the compounds in the mixture with boiling points below 204°C. Cresylic acids are the compounds with boiling points above 204°C. Cresols and cresylic acid are produced as by-products of either coal tar distillation or petroleum naphtha cracking.

As a by-product of coal tar distillation, cresols and cresylic acids are obtained from the middle light oil cut of the distillation and from the filtrate remaining after crystallization of the naphthalene, which is also present in the middle light oil. Extraction of the filtrate with sodium hydroxide removes phenols, cresols, and xylenols. After separation in an aqueous layer, the phenols are acidifed to yield an organic layer which is then distilled to yield natural phenol, cresols, and xylenols. The crude cresol cut is further purified by fractional distillation to yield ortho-cresol and a mixture consisting of meta- and para-cresol. In the thermal cracking of naphtha and gas oil fractions, petroleum acids are obtained which can be processed by methods similar to the cresol recovery processes used by the coal tar distillation.[1]

p-Cresol is also produced synthetically by methylation of phenol.

There are currently six producers of mixed cresols. The locations of the plants and the 1978 capacity and estimated production level for each plant are shown in Table 10-1.[1] In 1978 an estimated 32 million lb of mixed cresols was produced. The average composition of the three isomers in the mixed cresols produced is estimated to have been 26% p-cresol, 31% o-cresol, and 43% m-cresol.[2,3]

There are also currently seven producers of cresylic acid. The locations of the plants and the 1978 capacity and estimated production of each are shown in Table 10-1. In 1978 an estimated 47 million lb of cresylic acid was produced. The average composition of the three isomers in the cresylic acid produced is estimated to

Table 10-1. Mixed Cresols and Cresylic Acid Producers[a]

Company	Location	Tar Acids Capacity (million lb/yr)	Cresols or Cresylic Acid Produced (million lb/yr)	Geographic Coordinates (Latitude/Longitude)
		Mixed Cresols Producers		
Continental Oil	Newark, NJ	50	6	40 43 34/74 07 26
Fallek	Tuscaloosa, AL	20	2	33 11 00/87 34 50
Ferro	Sante Fe Springs, CA	30	4	33 56 30/118 04 18
Koppers	Oil City, PA	35	4	41 29 30/79 43 20
Merichem	Houston, TX	100	12	29 45 36/95 10 48
Stimson	Anacartes, WA	30	4	48 28 31/122 32 48
Total		265	32	
		Cresylic Acid Producers		
Continental Oil	Newark, NJ	50	9	40 43 34/74 07 26
Fallek	Tuscaloosa, AL	20	3	33 11 00/87 34 50
Ferro	Sante Fe Springs, CA	30	5	33 56 30/118 04 18
Koppers	Follansbee, WV	35	6	40 23 10/80 35 07
Merichem	Houston, TX	100	17	29 45 36/95 10 48
Mobil Oil	Beaumont, TX	10	2	34 04 14/94 03 40
Stimson	Anacortes, WA	30	5	48 28 31/122 32 48
Total		275	47	

[a] See ref. 1.

have been 35% p-cresol, 3% o-cresol, and 34% m-cresol. The remaining 28% of cresylic acid is made up primarily of xylenols.[1]

Some of the cresols/cresylic acid manufacturers also produce individual isomers, with o- and m-cresols removed by extraction and distillation of the coal tars and petroleum fractions. p-Cresol isomer is produced synthetically.

There are currently six producers of o-cresol isomer in the United States. The locations of the plants and the 1978 capacity and production levels are shown in Table 10-2.[1] An estimated 30 million lb of o-cresol was produced in 1978.

Sherwin Williams at its Chicago, Illinois, plant produced an estimated 21 million lb of p-cresol synthetically in 1978. The plant location is shown in Table 10-2.

There were two m-cresol isomer producers in 1978 that manufactured an estimated 1.5 million lb. Source locations are shown in Table 10-2.[1]

A summary of the estimated cresol isomer composition of mixed cresols, cresylic acids, and a mixture of the two as used in 1978 is given in Table 10-3.[1,2,3]

B. USES

Table 10-4[1,4] shows the end-use distribution of the individual cresol isomers, the mixed cresols, and cresylic acid.

The manufactaure of 2,6-ditert butyl-p-cresol (BHT), which is used as a food preservative, consumed half of the o-cresol isomer production (15 million lb). Antioxidant manufacture consumed an estimated 10 million lb with the remainder being exported (5 million lb).

The majority of the p-cresol isomer produced was exported. Estimated exports in 1978 were 10.5 million lb, representing 50% of production. An estimated 5.5 million lb was consumed in phenolic resin manufacture, and 5.0 million lb was used to produce pesticides.

m-Cresol isomer production was used exclusively in the manufacture of pyrethroid pesticides (1.5 million lb).

Table 10-2. Cresol Isomer Producers[a]

Company	Location	Cresol Isomer Capacity (million lb/yr)	Cresol Isomer Produced (million lb/yr)	Geographic Coordinates (Latitude/Longitude)
		o-Cresol Producers		
Continental Oil	Newark, NJ	7.7	5.0	40 43 34/74 07 26
Fallek Chemical	Tuscaloosa, AL	9.6	6.0	33 11 00/87 34 50
Ferro Corp.	Sante Fe Springs, CA	4.5	3.0	33 56 30/118 04 18
Koppers	Oil City, PA	5.4	3.0	41 29 30/79 43 20
Merichem	Houston, TX	15.1	10.0	29 45 36/95 10 48
Stimson	Anacortes, WA	4.5	3.0	48 28 31/122 32 48
Total		46.8	30.0	
		p-Cresol Producer		
Sherwin Williams	Chicago, IL	NA[b]	21.0	41 43 04/87 36 30
		m-Cresol Producers		
Koppers	Oil City, PA	NA[b]	0.75	41 29 30/79 43 20
Merichem	Houston, TX	NA[b]	0.75	29 45 36/95 10 48
Total			1.50	

[a] See ref. 1.

[b] Not available.

Table 10-3. Cresol Isomer Compositions*

In mixed cresol 3 (both product and emissions)	
26%	p-cresol
31%	o-cresol
43%	m-cresol
100%	
In cresylic acid (both product and emissions)	
35%	p-cresol
3%	o-cresol
34%	m-cresol
28%	others, mainly xylenols
In mixed cresol/cresylic acid end-use (combined) and emissions	
31.6%	p-cresol
13.7%	o-cresol
37.4%	m-cresol
17.3%	others (mainly xylenols)

*See refs. 1, 2 and 3.

Table 10-4. 1978 End Use Distribution of Cresol Isomers, Cresols and Cresylic Acid*

End-Use	Isomer, Cresols, or Cresylic Acid Used (million lb/yr)	(%)
o-Cresol Isomer		
2,6-ditert butyl-p-cresol (BHT)	15.0	50
Antioxidants	10.0	33
Export	5.0	17
Total	30.0	100
p-Cresol Isomer		
Phenolic resins	5.5	26
Pesticides	5.0	24
Export	10.5	50
Total	21.0	100
m-Cresol Isomer		
Pyrethroid pesticides	1.5	100
Total	1.5	100
Mixed Cresols/Cresylic Acids (combined)		
Tricresyl phosphate (TCP)	31.0	32
Cresyl diphenol phosphate (CDP)		
Phenolic resins	20.0	21
Wire enamel solvent	20.0	21
Pesticides	8.0	8
Disinfectants/cleaning compound	3.0	3
Ore flotation	3.0	3
Miscellaneous other	7.0	7
Export	5.0	5
Total	97.0	100

*See refs. 1 and 4.

The only available data on the end-uses of mixed cresols and cresylic acid are in combined form. Total consumption of both mixed cresols and cresylic acid was 97 million lb with the difference between production (79 million lb) and use resulting from imports (18 million lb).

The largest end-use[5] of mixed cresols/cresylic acid was in tricresyl phosphate (plasticizer) manufacture (31 million lb), phenolic resins (20 million lb), and wire enamel solvent (20 million lb). Pesticide manufacture consumed 8 million lb; use in cleaning compounds and disinfectants for consumer use consumed 3 million lb; and use as an ore flotation agent consumed 3 million lb.

Other miscellaneous uses consumed 7 million lb, and exports accounted for 5 million lb.

Specific user locations for BHT producers, pyrethroid pesticide producers, and tricresyl phosphate producers are shown in Table 10-5.[5]

C. INCIDENTAL SOURCES

The major incidental source of cresol isomer emissions is coke ovens. Coal tars from coke ovens contain tar acids of 1.04% cresols.

Table 10-6[6] presents a list of coke oven plants in the U.S. Data to assign capacity and production to each site were not available. The total estimated coke production from these plants in 1978 was 107 billion lb.

II. EMISSION ESTIMATES

A. PRODUCTION

Emission factors used to develop production and end-use emission estimates for the isomers, mixed cresols, and cresylic acid are shown in Table 10-7.

Emissions from the production of mixed cresols and cresylic acid are shown in Table 10-8. Total cresol emissions from mixed cresol production were estimated to have been 80,000 lb in 1978. Of this total 24,800 lb were o-cresol, 20,800 lb were p-cresol, and 34,400 lb were m-cresol.

Table 10-5. Identified Source Locations of Cresols End-Users[a]

Company	Location	Production Capacity (lb/yr)	Cresol Usage (lb/yr)	Geographic Coordinates (Latitude/Longitude)
		o-Cresol Isomer		
2,6 di-tert-buty-p-cresol (BHT) Producers				
Ashland	Fords, NJ	12	5	40 31 20/74 20 50
Koppers	Oil City, PA	9	4	41 29 30/79 43 20
Shell	Martinez, CA	10	4	38 00 05/122 06 40
Uniroyal	Geismar, LA	5	2	30 13 30/91 00 15
Total		36	15	
		m-Cresol Isomer		
Pyrethroid Pesticide Producers				
CPC International	Lyndhurst, NJ	NA[b]	0.5	40 47 30/74 04 34
FMC	Baltimore, MD	NA	0.5	39 14 50/76 35 30
Vertac	West Helena, AR	NA	0.5	34 36 10/90 33 45
Total			1.5	
		Mixed Cresols/Cresylic Acid		
Tricresyl Phosphate/Cresyl Diphenyphosphate Producers				
FMC	Nitro, WV	60	20	38 25 33/81 50 05
Stauffer	Gallipolis Ferry, WV	35	11	38 46 40/82 10 54
Total		95	31	

[a] See ref. 5.

[b] Not available.

Table 10-6. Coke-Oven Plants in the United States*

Company	Location
Alabama By-Products Corporation	Tarrant, Alabama
Alan Wood Steel Company	Swedeland, Pennsylvania
Allied Chemical Corporation	
Semet-Solvay Division	Ashland, Kentucky Detroit, Michigan
Armco Steel Corporation	Hamilton, Ohio Houston, Texas Middletown, Ohio
Bethlehem Steel Corporation	Bethlehem, Pennsylvania Burns Harbor, Indiana Johnstown, Pennsylvania Lackawana, New York Sparrows Point, Maryland
Chattanooga Coke & Chemical Co. Inc.	Alton Park, Tennessee
Citizens Gas & Coke Utility	Indianapolis, Indiana
Colorado Fuel & Iron Steel Corporation	Pueblo, Colorado
Colt Industries Inc.	
Crucible Stainless Steel and Alloy Division	Midland, Pennsylvania
Cyclops Corporation	
Empire-Detroit Steel Division	Portsmouth, Ohio
Donner-Hanna Coke Corporation (jointly owned by Republic Steel Corporation and Hanna Furnace Corporation, a subsidiary of National Steel Corporation)	Buffalo, New York
Eastern Gas and Fuel Associates	
Eastern Associated Coal Corp., subsidiary	Philadelphia, Pennsylvania
Empire Coke Company	Holt, Alabama
Ford Motor Company	
Steel Division	Rouge, Michigan
Great Lakes Carbon Corporation	
Missouri Coke and Chemical Division	St. Louis, Missouri
Indiana Gas & Chemical Corporation	Terre Haute, Indiana
Inland Steel Company	Indiana Harbor, Indiana
Interlake, Inc.	South Chicago, Illinois Toledo, Ohio

Table 10-6 (Continued)

Company	Location
International Harvestor Company	
Wisconsin Steel Division	South Chicago, Illinois
Jones & Laughlin Industries, Inc.	
(owned by the LTV Corporation) Jones & Laughlin Steel Corp., subsidiary	Aliquippa, Pennsylvania Pittsburgh, Pennsylvania
Kaiser Steel Corporation	Fontana, California
Koppers Company, Inc.	
Organic Material Division	Erie, Pennsylvania St. Paul, Minnesota Woodward, Alabama
Lykes Corporation	
Youngstown Sheet and Tube Company, subsidiary	Campbell, Ohio Indiana Harbor, Indiana
McClouth Steel Corporation*	Ironton, Ohio
Milwaukee Solvay Coke Company	
(affiliated with Pickands Mather & Co., subsidiary of Moore and McCormick Co., Inc.)	Milwaukee, Wisconsin
National Steel Corporation	
Granite City Steel Division	Granite City, Illinois
Great Lakes Steel Division B. F. Division	Zug Island, Michigan
Weirton Steel Division	Weirton, West Virginia
Northwest Industries, Inc.	
Lone Star Steel Company, subsidiary	Daingerfield, Texas
NVF Company	
Sharon Steel Corporation, subsidiary	Fairmont, West Virginia
Republic Steel Corporation	
Iron and Chemical Division	Chicago, Illinois Cleveland, Ohio Gadsden, Alabama Massillon, Ohio Thomas, Alabama Warren, Ohio Youngstown, Ohio

*McClouth Steel Corporation purchased only the coking operations of Allied Chemical Corporation's Ironton, Ohio, facility in 1977. By-products are still manufactured by Allied.

Table 10-6 (Continued)

Company	Location
Shenango Incorporated	
(owned by The Shenango Furnace Company)	Neville Island, Pennsylvania
Tonawanda Coke Corporation	Buffalo, New York
United States Steel Corporation	
USS Agri-Chemicals Division and USS Chemicals Division	Clairton, Pennsylvania Duluth, Minnesota Fairfield, Alabama Fairless Hills, Pennsylvania Gary, Indiana Geneva, Utah Lorain, Ohio
Jim Walter Corporation	
Jim Walter Resources, Inc., subsidiary	
Chemical Division	Birmingham, Alabama
Wheeling-Pittsburgh Steel Corporation	East Steubenville, West Virginia Monessen, Pennsylvania

*See ref. 6.

Table 10-7. Cresols Production and End-Use Emission Factors

Source	lb Lost per lb Produced (Used)				Derivation[a]
	Process	Storage	Fugitive	Total	
Mixed cresol production	0.00190	0.00020	0.00040	0.00250	B[b]
Cresylic acid production	0.00190	0.00020	0.00040	0.00250	B[b]
p-Cresol production	0.0039	0.00030	0.00080	0.00500	D
BHT/antioxidants	0.0008	0.0001	0.0001	0.001	D
Phenolic resins	0.00400	0.0005	0.0005	0.00500	D
Pesticides	0.00040	0.00005	0.00005	0.00050	C[c]
Pyrethroid pesticides	0.00040	0.00005	0.00005	0.00050	D
TCP production	0.00035	0.00005	0.00010	0.0005	C[b]
Miscellaneous, other				0.001[d]	

[a] Basis:
A - site visit data
B - state files
C - published data
D - Hydroscience estimate

[b] See ref. 7.

[c] See ref. 8.

[d] Based on a weighted average of all of cresol uses.

Table 10-8. Cresol Emissions from Mixed Cresol, Cresylic Acid Producers

Company	Location	Emissions (lb/yr)			Total Cresol Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
		Mixed Cresols Producers				
Continental Oil	Newark, NJ	11,400	6,400	2,400	15,000	0.22
Fallek	Tuscaloosa, AL	3,800	400	800	5,000	0.07
Ferro	Santa Fe Springs, CA	7,600	800	1,600	10,000	0.14
Koppers	Oil City, PA	7,600	800	1,600	10,000	0.14
Merichem	Houston, TX	22,800	2,400	4,800	30,000	0.43
Stimson	Anacortes, WA	7,600	800	1,600	10,000	0.14
Total		60,800	6,400	12,800	80,000	
Continental Oil	Newark, NJ	17,100	1,800	3,600	22,500	0.32
Fallek	Tuscaloosa, AL	5,700	600	1,200	7,500	0.11
Ferro	Santa Fe Springs, CA	9,500	1,000	2,000	12,500	0.18
Koppers	Follansbee, WV	11,400	1,200	2,400	15,000	0.22
Merichem	Houston, TX	32,300	3,400	6,800	42,500	0.61
Mobil Oil	Beaumont, TX	3,800	400	800	5,000	0.07
Stimson Lumber	Anacortes, WA	9,500	1,000	2,000	12,500	0.18
Total		89,300	9,400	18,800	117,500	

*Based on 8760 hr/yr operation.

Total cresylic acid production emissions were estimated to have been 117,500 lb. Of this total 3,525 lb were o-cresol, 41,125 lb were p-cresol, and 39,950 lb were m-cresol.

Since both mixed cresols and cresylic acid share common producing sites, and in the absence of other emission data, the same emission factor of 0.00250 was used to estimate emissions for both. It was assumed that the cresol isomer composition in the emissions was the same as in the product mixtures shown in Table 10-3.

Process vent emissions originate primarily from distillation and neutralizaton processes. Storage emissions represent the losses from both working and final product storage as well as loading and handling. Fugitive emissions are those which result from plant equipment leaks.

Emissions from the individual isomer production are shown in Table 10-9. The emission factor used for m- and o-cresol production losses is the same that was used for mixed cresols. The p-cresol emission factor used was 0.005 lb/lb since it is synthetically manufactured.

Emissions from o-cresol, p-cresol, and m-cresol individual isomer production were estimated to have been 75,000 lb, 105,000 lb, and 3,750 lb respectively.

B. USES

The emissions from specific end-user locations are shown in Table 10-10 for p-cresol isomer used in BHT production, m-cresol isomer used in pyrethroid pesticide production, and mixed cresols/cresylic acid used in TCP production Emission estimates were developed using the emission factors shown in Table 10-7.

o-Cresol emissions from BHT production were 15,000 lb. Emissions resulting from its use in antioxidant manufacture were estimated to be 10,000 lb. Specific manufactures and locations for regional distribution of antioxidant emissions were not available.

Emissions from m-cresol use were estimated to have been 750 lb. Emissions were distributed evenly over all three sites in the absence of capacity data.

Table 10-9. Cresol Isomer Emissions from Cresol Isomer Producers

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
		o-Cresol Producers				
Continental Oil	Newark, NJ	9,500	1,000	2,000	12,500	0.18
Fallek	Tuscaloosa, AL	11,400	1,200	2,400	15,000	0.22
Ferro	Santa Fe Springs, CA	5,700	600	1,200	7,500	0.11
Koppers	Oil City, PA	5,700	600	1,200	7,500	0.11
Merichem	Houston, TX	19,000	2,000	4,000	25,000	0.36
Stimson	Anacortes, WA	5,700	600	1,200	7,500	0.11
Total		57,000	6,000	12,000	75,000	
		p-Cresol Producer				
Sherwin-Williams	Chicago, IL	81,900	6,300	16,800	105,000	1.51
Total		81,900	6,300	16,800	105,000	
		m-Cresol Producers				
Koppers	Oil City, PA	1,425	150	300	1,875	0.03
Merichem	Houston, TX	1,425	150	300	1,875	0.03
Total		2,850	300	600	3,750	

*Based on 8760 hr/yr operation.

Table 10-10. Cresol Emissions from Cresol Users

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
		o-Cresol Isomer				
2,6-Di-tert-buty-p-cresol (BHT) producers						
Ashland	Fords, NJ	4,000	500	500	5,000	0.07
Koppers	Oil City, PA	3,200	400	400	4,000	0.06
Shell	Martinez, CA	3,200	400	400	4,000	0.06
Uniroyal	Geismar, LA	1,600	200	200	2,000	0.03
Total		12,000	1,500	1,500	15,000	
		m-Cresol Isomer				
Pyrethroid pesticide producers						
CPC International	Lyndhurst, NJ	200	25	25	250	0.004
FMC	Baltimore, MD	200	25	25	250	0.004
Vertac	West Helena, AR	200	25	25	250	0.004
Total		600	75	75	750	
		Mixed Cresols/Cresylic Acid				
Tricresyl phosphate/cresyl diphenylphosphate producers						
FMC	Nitro, WV	7,000	1,000	2,000	10,000	0.14
Stauffer	Gallipolis Ferry, WV	5,500	550	1,100	5,500	0.08
Total		12,500	1,550	3,100	15,500	

*Based on 8760 hr/yr operation.

Emissions from the use of cresols/cresylic acid to manufacture TCP were estimated to have been 15,500 lb. Of that total 2120 lb were o-cresol, 4900 lb were p-cresol, and 5800 lb were m-cresol.

Other sources of cresol emissions had to be handled on a regional basis because of their widespread use.

Emissions of p-cresol isomer and cresol/cresylic acid used to produce phenolic resins are summarized in Table 10-11 by geographic region. Emissions from this end-use were estimated to have been 13,700 lb o-cresol, 37,400 lb m-cresol, and 31,600 lb p-cresol. In addition, 27,500 lb of p-cresol was lost when used as an individual isomer for phenolic resins production. Total emissions of all isomers were distributed based on the number of sites in each region.

The emissions of p-cresol isomer and cresol/cresylic acid used to produce pesticides are shown in Table 10-12 by geographic region. Emissions from this end-use were estimated to have been 1265 lb p-cresol, 550 lb o-cresol, and 2185 lb m-cresol from cresol/cresylic acid use. In addition, 2500 lb p-cresol was lost from its use as an individual isomer in pesticide production. Total emissions were distributed by the number of sites in each region.

The emissions of cresols in wire enamel solvents are shown in Table 10-13. Emissions were developed by assuming that all cresols used in this solvent application are lost and that the emission composition of cresol isomers is the same as the end-use production shown in Table 10-3. Emissions were estimated to have been 2,740,000 lb o-cresol, 6,320,000 pcresol, and 7,480,000 m-cresol. Emissions were distributed over the number of paint and lacquer sites in the U.S. in the absence on any other distributable data.

Emissions from cresols/cresylic acid used in ore flotation were estimated to have been 411,000 lb o-cresol, 1,122,000 lb m-cresol, and 948,000 p-cresol in 1978. Emissions are summarized and distributed in Table 10-14 by the number of mining sites in the U.S.

Emissions from coke ovens were estimated to have been 796,080 lb o-cresol, 1,104,240 lb m-cresol, and 667,680 lb p-cresol in 1978. Emissions were

Table 10-11. Cresol Isomer Emissions from Phenolic Resin Producers by Region[a]

			p-Cresol Emissions		
Region	Number of Sites	o-Cresol Emissions (lb/yr)	From Isomer (lb/yr)	From Cresols/ Cresylic Acid (lb/yr)	m-Cresol Emissions (lb/yr)
New England	6	660	1,320	1,500	1,800
Middle Atlantic	26	2,860	5,720	6,500	7,800
East North Central	31	3,410	6,820	7,750	9,300
West North Central	5	550	1,100	1,250	1,500
South Atlantic	15	1,650	3,300	3,750	4,500
East South Central	6	660	1,320	1,500	1,800
West South Central	11	1,210	2,420	2,750	3,300
Mountain	1	110	220	250	300
Pacific	24	2,640	5,280	6,000	7,200
Total	125	13,700[b]	27,500[c]	31,600[d]	37,400[e]

[a] See ref. 9.

[b] Average 110 lb/yr per site.

[c] Average 220 lb/yr per site.

[d] Average 250 lb/yr per site.

[e] Average 300 lb/yr per site.

Table 10-12. 1978 Cresol Isomer Emission Estimates from Pesticide Manufacturers[a]

Region	Number of Sites	p-Cresol		o-Cresol in Mixed Cresols/ Cresylic Acid (lb/yr)	m-Cresol in Mixed Cresols/ Cresylic Acid (lb/yr)
		As Isomer (lb/yr)	In Mixed Cresols/ Cresylic Acid (lb/yr)		
New England	4	72	36	16	63
Middle Atlantic	37	666	337	148	581
East North Central	19	342	173	76	298
West North Central	15	270	137	60	236
South Atlantic	17	306	155	68	267
East South Central	14	250	127	56	220
West South Central	15	270	137	60	236
Mountain	5	90	46	20	79
Pacific	13	234	118	52	204
Total	139	2500[b]	1265[c]	550[d]	2185[e]

[a] See ref. 10.

[b] Average 18 lb/yr per site.

[c] Average 9.1 lb/yr per site.

[d] Average 4.0 lb/yr per site.

[e] Average 15.7 lb/yr per site.

Table 10-13. Cresol Isomer Emissions from Mixed Cresols/Cresylic Acid Used as Wire Enamel Solvent[a]

Region	Number of Sites	o-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)
New England	46	79,975	184,465	218,325
Middle Atlantic	339	589,380	1,359,440	1,608,960
East North Central	370	643,275	1,483,755	1,756,090
West North Central	84	146,040	336,855	398,680
South Atlantic	174	302,510	697,765	825,835
East South Central	44	76,500	176,445	208,830
West South Central	87	151,255	348,885	412,920
Mountain	258	448,555	1,034,620	1,224,520
Pacific	174	302,510	697,765	825,840
Total	1,576	2,740,000	6,320,000	7,480,000

[a] See ref. 11.

[b] Average 1738.6 lb/yr per site.

[c] Average 4010.2 lb/yr per site.

[d] Average 4746.2 lb/yr per site.

Table 10-14. Cresol Isomer Emissions from Mixed Cresol/Cresylic Acid Used as an Ore Flotation Agent[a]

Region	Number of (Mining) Sites	o-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)
New England	6	4,382	11,957	10,103
Middle Atlantic	38	27,750	75,729	63,987
East North Central	85	62,075	169,392	143,128
West North Central	145	105,890	288,964	244,159
South Atlantic	62	45,275	123,557	104,399
East South Central	40	29,211	79,714	67,354
West South Central	21	15,336	41,850	35,361
Mountain	144	105,161	286,971	242,475
Pacific	22	16,066	43,843	37,045
Total	563	411,000[b]	1,122,000[c]	984,000[d]

[a] See ref. 12.

[b] Average 730 lb/yr per site

[c] Average 1993 lb/yr per site.

[d] Average 1684 lb/yr per site.

estimated by assuming that for 107 billion lb coke produced, 0.000024 lb of cresols would be lost per pound of coke produced. Composition of the cresols is the same as the mixed cresols product composition shown in Table 10-3. Emissions are summarized and distributed in Table 10-15 by the number of coke oven sites in each region.

Emissions from the solvent use of cresols/cresylic acid as a disinfectant/cleaning compound were estimated to have been 411,000 lb o-cresol, 948,000 lb p-cresol, and 1,122,000 m-cresol. Emissions are considered widespread in proportion with population.

Miscellaneous uses as a chemical intermediate are too widespread to allow for regional distribution. Emission estimates were made by using a weighted average emission factor of 0.001 lb lost/lb use derived from all other isomers, mixed cresols, and cresylic acid end-users. Emissions from miscellaneous uses were estimated to have been 1000 lb o-cresol, 2200 lb p-cresol, and 2600 lb m-cresol.

Vent parameter data for both production and end-uses of cresols are summarized in Table 10-16.

The total nationwide emissions of o-cresol, p-cresol, and m-cresol are estimated to have been 4,503,775 lb, 9,120,570 lb, and 10,955,075 lb respectively. Total emissions are summarized in Tables 10-17, 10-18, and 10-19 for o-cresol, p-cresol and m-cresol, respectively.

Table 10-15. Cresol Isomer Emissions from Coke Oven Operations[a,b]

Region	Number of Sites	o-Cresol Emissions (lb/yr)	m-Cresol Emissions (lb/yr)	p-Cresol Emissions (lb/yr)	Total Cresol Emissions (lb/yr)
New England	0	0	0	0	0
Middle Atlantic	15	195,750	271,500	164,175	631,500
East North Central	25	326,250	452,500	273,625	1,052,500
West North Central	3	39,150	54,300	32,835	126,300
South Atlantic	4	52,200	72,400	43,780	168,400
East South Central	9	117,450	162,900	98,505	378,900
West South Central	2	26,100	36,200	21,890	84,200
Mountain	2	26,100	36,200	21,890	84,200
Pacific	1	13,050	18,100	10,945	42,100
Total	61	796,080[c]	1,104,240[d]	667,680[e]	2,568,000

[a] See ref. 6.

[b] Basis: 107 billion lb coke produced; 0.000024 lb cresols emitted/lb coke produced; cresol composition - 26% p-cresol, 31% o-cresol, and 43% m-cresol in mixed cresols emitted.

[c] Average 13,050 lb/yr per site.

[d] Average 18,100 lb/yr per site.

[e] Average 10,945 lb/yr per site.

Table 10-16. Cresol Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Production (all types)						
Process	2	30	1	208	75	
Storage	8	24	0.17	80		
Fugitive						300 X 600
BHT/TCP production						
Process	1	60	0.5	150	35	
Storage	4	16	0.17	80		
Fugitive						100 X 100
Phenolic resins						
Process	1	60	0.33	150	20	
Storage	1	16	0.17	80		
Fugitive						100 X 100
Pesticides/pyrethroids						
Process	1	30	0.17	100	15	
Storage	2	20	0.17	80		
Fugitive						100 X 100
Wire enamel solvent						
Process	1	40	0.25	120	10	
Ore flotation						
Process	1	20	0.25	120	10	

Building cross-section: Production - 200 m^2; BHT/TCP - 100 m^2; Phenolic Resins - 50 m^2; Pesticides - 100 m^2; Wire Enamel Solvent 0 200 m^2; Ore Flotation - 50 m^2.

Table 10-17. 1978 Nationwide o-Cresol Emissions

Source	Nationwide Emissions (lb/yr)
o-Cresol production	75,000
Mixed cresol production	24,800
Cresylic acid production	3,525
BHT production	15,000
Antioxidants production	10,000
Tricresyl phosphate production	2,120
Phenolic resins	13,700
Wire enamel solvent	2,740,000
Pesticides	550
Disinfectants/cleaning compounds	411,000
Ore flotation agent	411,000
Miscellaneous, other	1,000
Coke ovens	796,080
Total	4,503,775

Table 10-18. 1978 Nationwide p-Cresol Emissions

Source	Nationwide Emissions (lb/yr)
p-Cresol production	105,000
Mixed cresol production	20,800
Cresylic acid production	41,125
Phenolic resins production (isomer)	27,500
Pesticides production	2,500
Tricresyl phosphate	4,900
Phenolic resins	31,600
Wire enamel solvent	6,320,000
Pesticides	1,265
Disinfectants/cleaning compounds	948,000
Ore flotation agent	948,000
Miscellaneous, other	2,200
Coke ovens	667,680
Total	9,120,570

Table 10-19. 1978 Nationwide Emissions m-Cresol

Source	Nationwide Emissions (lb/yr)
m-Cresol production	3,750
Mixed cresol production	34,400
Cresylic acid production	39,950
Pyrethroid pesticide	750
Tricresyl phosphate	5,800
Phenolic resins	37,400
Wire enamel solvent	7,480,000
Pesticides	2,185
Disinfectants/cleaning compounds	1,122,000
Ore flotation agent	1,122,000
Miscellaneous, other	2,600
Coke ovens	1,104,240
Total	10,955,075

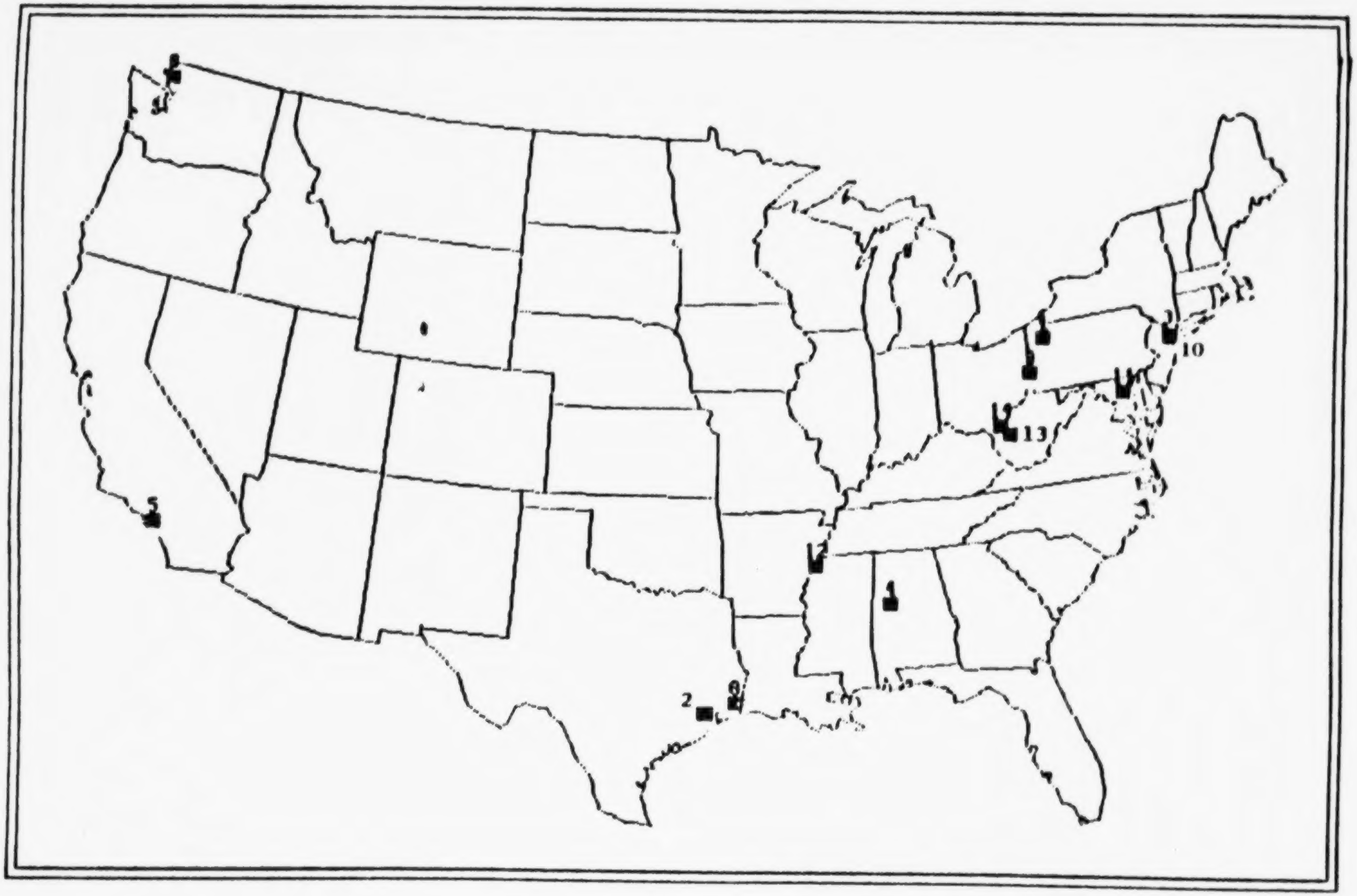


FIGURE 10-1. SPECIFIC POINT SOURCES OF m-CRESOL EMISSIONS

TABLE 10-20. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF m-CRESOL

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	1	1 2	.020520 .047088	.002160 .004896	.004320 .009936
2	MEKICHEM	HOUSTON, TX	29 45 36	095 10 48	12906	2	1 2 3	.020520 .141120 .158112	.002160 .014832 .016704	.004320 .029664 .033264
3	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	3	2 3	.070560 .083664	.039600 .008784	.014832 .017568
4	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	3	2 3	.023472 .027936	.002448 .002880	.004896 .005904
5	FERRO	SANTA FE S, CA	33 56 30	118 04 12	93106	3	2 3	.047088 .027936	.004896 .002880	.009936 .005904
6	STINSON	ANACORTES, WA	48 28 31	122 32 48	24217	3	2 3	.047088 .046512	.004896 .004896	.009936 .009792
8	MOBIL OIL	BEAUMONT, TX	30 04 14	094 03 40	12917	4	3	.158112	.016704	.033264
9	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	4	3	.055872	.005904	.011808
10	CPC	LYNDHURST, NJ	40 47 30	074 04 34	94741	5	4	.002880	.000360	.000360
11	FMC	BALTIMORE, MD	39 14 50	076 35 30	93721	5	4	.002880	.000360	.000360
12	VERTAC	WEST HELENA, AR	34 36 10	090 33 45	13959	5	4	.002560	.000360	.000360
13	FMC	NITRO, WV	38 25 33	081 50 05	13866	6	5	.037728	.005328	.010800
14	STAUFFER	CALLIPOLIS FY, WV	38 46 40	082 10 54	13866	6	5	.029664	.002966	.005904

[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 10-20. (Concluded)

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* Plant Types:

Type 1: Plant produces isolated m-cresol and mixed cresols
Type 2: Plant produces isolated m-cresol, mixed cresols, and cresylic acid
Type 3: Plant produces mixed cresols and cresylic acid
Type 4: Plant produces cresylic acid
Type 5: Plant produces pyrethroid pesticide
Type 6: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: Isolated m-cresol production
Type 2: Mixed cresols production
Type 3: Cresylic acid production
Type 4: Pyrethroid pesticide production
Type 5: Tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP) production

TABLE 10-21. EXPOSURE AND DOSAGE OF m-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
2.5	41	107
1	246	425
0.5	1,171	1,120
0.25	5,010	2,390
0.1	27,102	5,850
0.05	63,501	8,380
0.025	272,402	15,200
0.01	1,003,356	26,500
0.005	2,747,945	38,300
0.0025	6,360,348	51,000
3.5×10^{-6}*	19,505,952	57,800

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-22. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF m-CRESOL

Region	Resins Production		Wire Enamel Solvent		Pesticide Production		Ore Flotation		Coke Oven	
	Emission/Site (gm/sec)	Number of Sites	Emission/Site (gm/sec)	Number of Sites	Emission/Site (gm/sec)	Number of Sites	Emission/Site (gm/sec)	Number of Sites	Emission/Site (gm/sec)	Number of Sites
New England	0.00431	6	0.0683	46	0.000155	4	0.0287	6	0	0
Middle Atlantic	0.00431	26	0.0683	339	0.000155	37	0.0287	38	0.261	15
East North Central	0.00431	31	0.0683	370	0.000155	19	0.0287	85	0.261	25
West North Central	0.00431	5	0.0683	84	0.000155	15	0.0287	145	0.261	3
South Atlantic	0.00431	15	0.0683	174	0.000155	17	0.0287	62	0.261	4
East South Central	0.00431	6	0.0683	44	0.000155	14	0.0287	40	0.261	9
West South Central	0.00431	11	0.0683	87	0.000155	15	0.0287	21	0.261	2
Mountain	0.00431	1	0.0683	258	0.000155	5	0.0287	144	0.261	2
Pacific	0.00431	24	0.0683	174	0.000155	13	0.0287	22	0.261	1

TABLE 10-23. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF m-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)						Dosage [$10^3(\mu g/m^3)$ • persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5	0	0.7	0	0	11	11.7	0	0	0	0	0.08	0.08
2.5	0	41	0	0	32	73	0	0.14	0	0	0.16	0.29
1	0	363	0	3	107	474	0	0.6	0	0.004	0.27	0.87
0.5	0	1,040	0	32	261	1,340	0	1.1	0	0.02	0.38	1.5
0.25	0	2,510	0	132	767	3,410	0	1.6	0	0.06	0.55	2.2
0.1	--	--	--	--	--	--	0	2.6	0	0.10	0.75	3.4
0.05	--	--	--	--	--	--	0	3.4	0	0.14	0.91	4.5
0.025	--	--	--	--	--	--	0	4.4	0	0.19	1.1	5.7
0.01	--	--	--	--	--	--	0	5.6	0	0.27	1.4	7.2
0	--	--	--	--	--	--	0.04	10.4	0.002	0.35	1.8	13

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 10-24. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF m-CRESOL

Parameter	Value
Daytime decay rate (K_d)	1.68×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	16.20 gm/sec
Cleaning solvent	16.16 gm/sec
Miscellaneous	0.04 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 10-25. m-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level (μg/m³)	Population (person)	Dosage (μg/m³/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.050000	505140	42338.5	0.	100.0	0.	100.0	0.	0.
.025000	9149730	274137.2	0.	100.0	0.	100.0	0.	0.
.010000	23637585	464245.9	0.	100.0	0.	100.0	0.	0.
.005000	51757583	654161.0	0.	100.0	0.	97.8	.7	1.5
.002500	123305988	914669.0	0.	100.0	0.	94.5	2.5	2.9
0.	158679135	973892.7	0.	100.0	0.	91.8	3.0	5.3

TABLE 10-26. EXPOSURE AND DOSAGE SUMMARY OF m-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	0	12,000	0	12,000	0	80,000	0	80,000
2.5	41	73,000	0	73,000	107	290,000	0	290,107
1	246	474,000	0	474,250	425	870,000	0	870,425
0.5	1,171	1,340,000	0	1,341,000	1,120	1,500,000	0	1,501,120
0.25	5,010	3,410,000	0	3,415,000	2,390	2,200,000	0	2,202,000
0.1	27,102	--	0	---	5,850	3,400,000	0	3,406,000
0.05	63,501	--	505,140	---	8,380	4,500,000	42,339	4,551,000
0.025	272,402	--	9,149,730	---	15,200	5,700,000	274,137	5,989,000
0.01	1,003,356	--	23,637,585	---	26,500	7,200,000	464,246	7,691,000
0.005	2,747,945	--	51,757,583	---	38,300	--	654,161	---
0.0025	6,360,348	--	123,305,988	---	51,000	--	914,669	---
0.001	---	--	--	---	---	--	--	---
0.0005	---	--	--	---	---	--	--	---
0	19,505,952	--	158,679,135	158,679,135	57,800	13,000,000	973,900	14,032,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

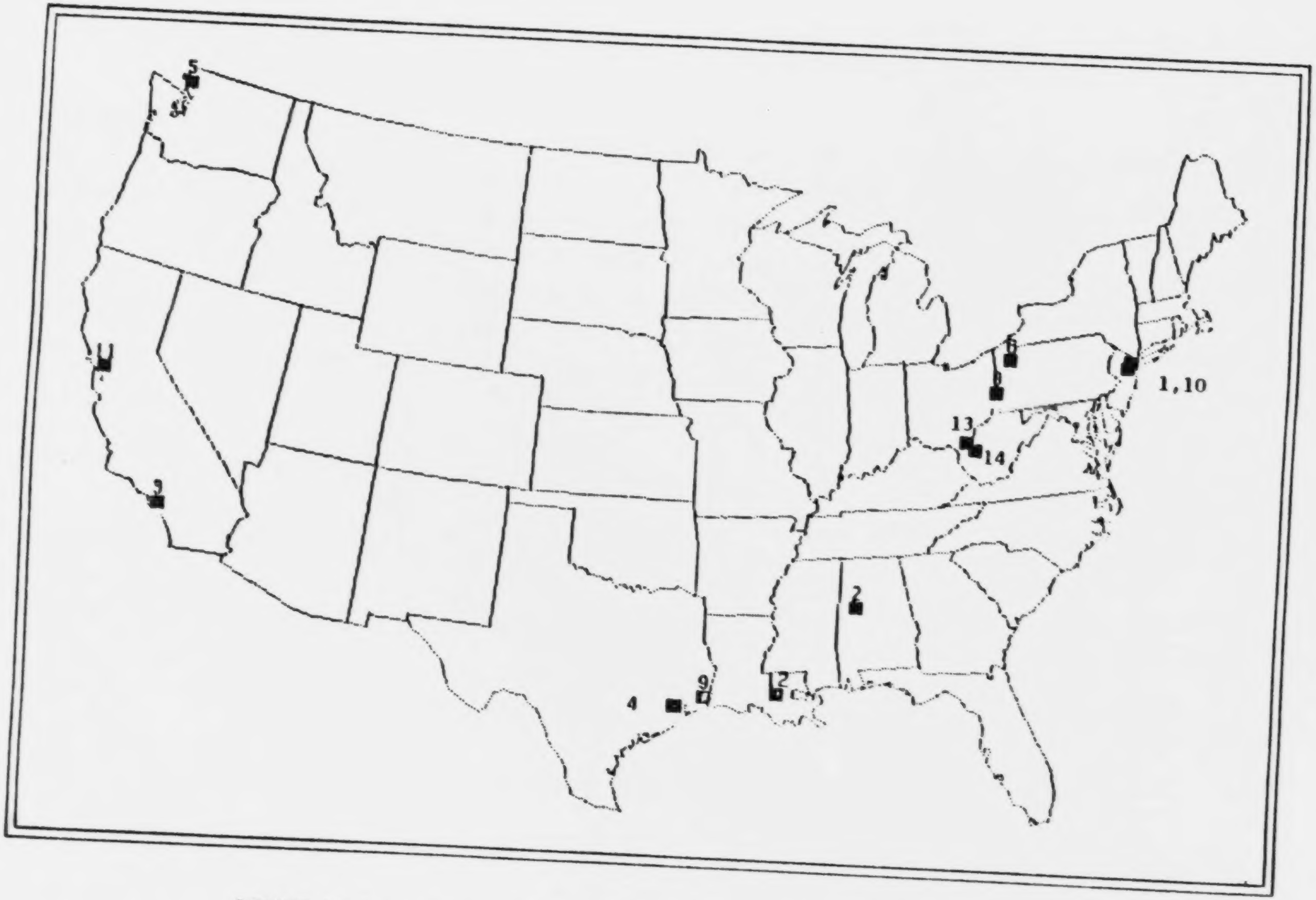
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FIGURE 10-2. SPECIFIC POINT SOURCES OF o-CRESOL EMISSIONS

TABLE 10-27. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF o-CRESOL

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	1	1 2 3	.136000 .050832 .007344	.014400 .020312 .000720	.028800 .010656 .001584
2	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	1	1 2 3	.164160 .016992 .002448	.017280 .001728 .000288	.034560 .003456 .000576
3	FERRO	SANTE FE SPRINGS, CA	33 56 30	118 04 10	93106	1	1 2 3	.082080 .033984 .004032	.000640 .003456 .000432	.017280 .007200 .000864
4	MERICHEM	HOUSTON, TX	29 43 36	095 10 40	12906	1	1 2 3	.273600 .101808 .013968	.028800 .010656 .001440	.057600 .021600 .002880
5	STIMSON	ANACORTES, WA	48 28 31	122 32 40	24217	1	1 2 3	.082080 .033984 .004032	.000640 .003456 .000432	.017280 .007200 .000864
6	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	2	1 2 4	.082080 .033984 .046080	.000640 .003456 .005760	.017280 .007200 .003760
8	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	3	3	.004896	.000576	.001008
9	MOBIL OIL	BEAMONT, TX	30 04 14	094 03 40	12917	3	3	.001584	.000144	.000288
10	ASHLAND	FORDS, NJ	40 31 22	074 20 50	04739	4	4	.057600	.007200	.007200
11	SHELL	MARTINEZ, CA	38 00 03	122 06 40	23202	4	4	.046080	.005760	.005760
12	UNIROYAL	GEISMAR, LA	30 13 30	091 00 15	12958	4	4	.023040	.002880	.002880
13	FMC	NITRO, WV	38 25 33	081 50 05	13866	5	5	.013824	.002016	.003888
14	STAUFFER	GALLIPOLIS FY, WV	38 46 40	082 10 54	13841	5	5	.010080	.001008	.002160

[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 10-27 (Concluded)

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* Plant Types:

Type 1: Plant produces isolated o-cresol, mixed cresols, and cresylic acid

Type 2: Plant produces isolated o-cresol, mixed cresols, and 2,6-di(t-butyl)-p-cresol (BHT)

Type 3: Plant produces cresylic acid

Type 4: Plant produces 2,6-di(t-butyl)-p-cresol (BHT)

Type 5: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: o-Cresol production

Type 2: Mixed cresols production

Type 3: Cresylic acid production

Type 4: 2,6-Di(t-butyl)-p-cresol (BHT) production

Type 5: Tricresyl phosphate (TCP) and cresyl diphonyl phosphate (CDP) production

TABLE 10-28. EXPOSURE AND DOSAGE OF o-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
2.5	2,712	13,100
1	13,213	28,500
0.5	25,326	37,000
0.25	49,636	45,100
0.1	198,570	68,000
0.05	532,426	90,300
0.025	1,315,167	118,000
0.01	2,136,688	131,000
0.005	4,039,816	144,000
0.0025	7,787,072	157,000
0.001	10,068,552	161,000
4.6×10^{-6}*	12,928,239	163,000

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-29. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF o-CRESOL

Region	Resins Production		Wire Enamel Solvent		Pesticide Production		Ore Flotation		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00158	6	0.0250	46	0.000057	4	0.0105	6	0.188	0
Middle Atlantic	0.00158	26	0.0250	339	0.000057	37	0.0105	38	0.188	15
East North Central	0.00158	31	0.0250	370	0.000057	19	0.0105	85	0.188	25
West North Central	0.00158	5	0.0250	84	0.000057	15	0.0105	145	0.188	3
South Atlantic	0.00158	15	0.0250	174	0.000057	17	0.0105	62	0.188	4
East South Central	0.00158	6	0.0250	44	0.000057	14	0.0105	40	0.188	9
West South Central	0.00158	11	0.0250	87	0.000057	15	0.0105	21	0.188	2
Mountain	0.00158	1	0.0250	258	0.000057	5	0.0105	144	0.188	2
Pacific	0.00158	24	0.0250	174	0.000057	13	0.0105	22	0.188	1

TABLE 10-30. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF o-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)						Dosage [$10^3(\mu g/m^3)$ • persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5	0	0	0	0	5	5	0	0	0	0	36	36
2.5	0	0	0	0	20	20	0	0	0	0	88	88
1	0	24	0	0	65	89	0	33	0	0	157	191
0.5	0	176	0	1.5	184	361	0	139	0	0.9	240	380
0.25	0	666	0	16	497	1,180	0	310	0	5.4	342	657
0.1	0	2,340	0	125	1,500	3,960	0	557	0	21	491	1,070
0.05	0	5,360	0	304	3,200	8,870	0	765	0	34	610	1,410
0.025	--	--	--	--	--	--	0.1	1,110	0	47	710	1,870
0.01	--	--	--	--	--	--	0.6	1,550	0	72	910	2,540
0.005	--	--	--	--	--	--	1.6	1,900	0	92	1,060	3,060
0	--	--	--	--	--	--	16	3,800	0.9	290	1,270	5,380

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 10-31. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF o-CRESOL

Parameter	Value
Daytime decay rate (K_d)	1.41×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	6.076 gm/sec
Cleaning solvent	5.918 gm/sec
Antioxidants production	0.144 gm/sec
Miscellaneous	0.014 gm/sec
National mobile source emissions	0

TABLE 10-32. o-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.025000	505140	15953.3	0.	100.0	0.	100.0	0.	0.
.010000	9149780	105758.2	0.	100.0	0.	100.0	0.	0.
.005000	17551646	152043.0	0.	100.0	0.	100.0	0.	0.
.002500	40810678	228322.1	0.	100.0	0.	100.0	0.	0.
.001000	119306114	340564.9	0.	100.0	0.	99.0	.2	.8
.000500	151204808	372300.6	0.	100.0	0.	94.7	2.4	2.9
0.	150679135	374759.0	0.	100.0	0.	92.4	2.9	4.7
					0.	91.9	2.9	5.2

TABLE 10-33. EXPOSURE AND DOSAGE SUMMARY OF o-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	0	5,000	0	5,000	5,000	0	0	36,000
2.5	2,712	20,000	0	20,146	22,712	13,100	0	101,100
1	13,213	89,000	0	90,381	102,213	28,500	0	219,500
0.5	25,326	361,000	0	365,400	386,300	37,000	0	417,000
0.25	49,636	1,180,000	0	1,193,000	1,230,000	45,100	0	702,100
0.1	198,570	3,960,000	0	4,000,600	4,158,600	68,000	0	1,138,000
0.05	532,426	8,870,000	0	8,930,000	9,402,400	90,300	0	1,500,300
0.025	1,315,167	--	505,140	--	---	118,000	15,955	2,004,000
0.01	2,136,688	--	9,149,730	--	---	131,000	105,758	2,816,800
0.005	4,039,816	--	17,551,646	--	---	144,000	152,043	3,356,000
0	12,928,239	--	158,679,135	--	---	163,000	374,759	5,917,800

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

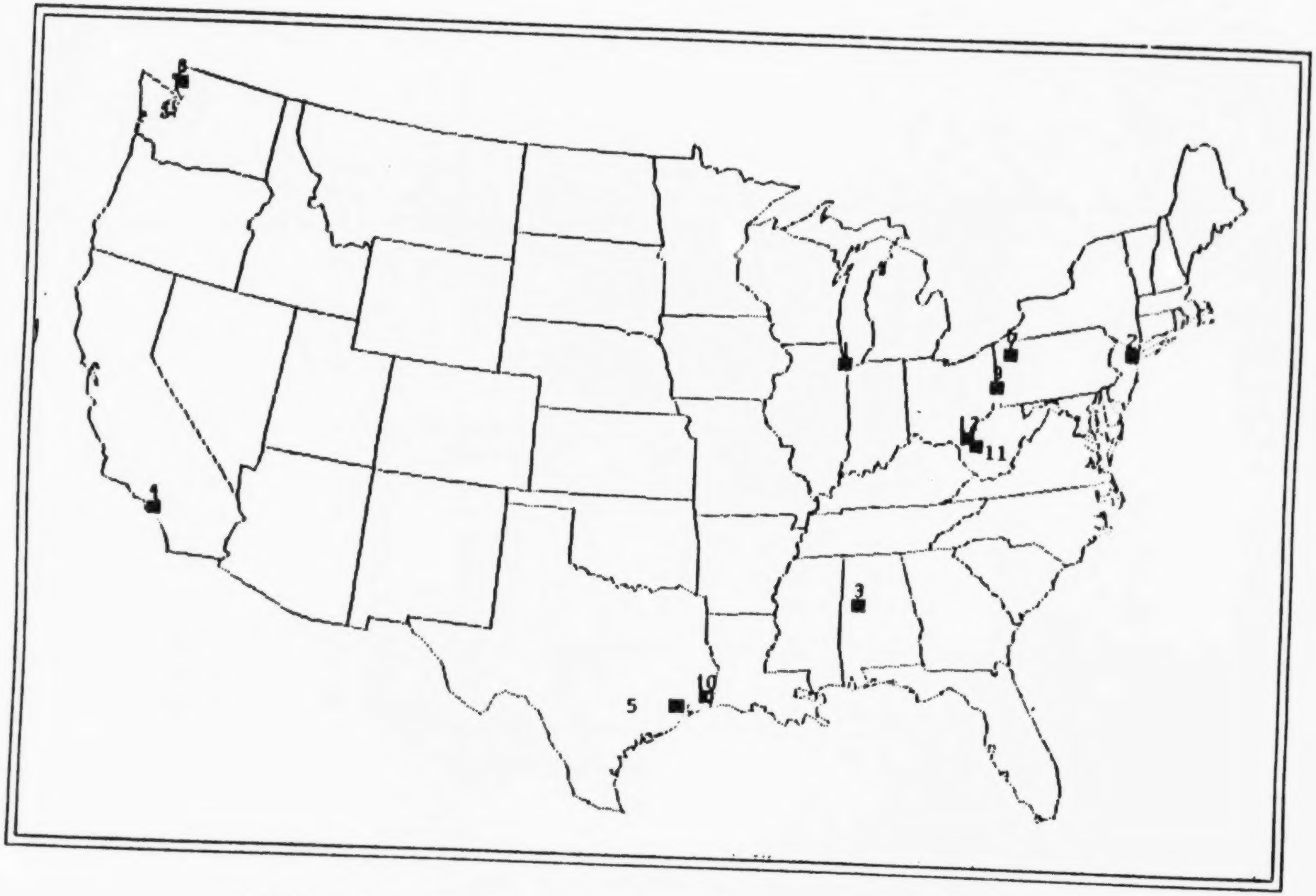
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FIGURE 10-3. SPECIFIC POINT SOURCES OF p-CRESOL EMISSIONS

TABLE 10-34. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-CRESOL

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	SHERWIN-WILLIAM	CHICAGO, IL	41 43 04	087 36 30	94846	1	1	1.179360	.090720	.241920
2	CONTINENTAL OIL	NEWARK, NJ	40 43 34	074 07 26	94741	2	2	.043624	.023904	.008928
							3	.086256	.009072	.015144
3	FALLEK	TUSCALOOSA, AL	33 11 00	087 34 50	93806	2	2	.014256	.001440	.003024
							3	.028800	.003024	.006048
4	FERRO	SANTA FE S, CA	33 56 30	118 04 18	93166	2	2	.028512	.003024	.006048
							3	.046368	.005040	.010080
5	MERICHEM	HOUSTON, TX	29 45 36	095 10 46	12906	2	2	.085392	.008928	.018000
							3	.162720	.017136	.034272
6	STIMSON	ANACORTEX, WA	48 28 31	122 32 48	24217	2	2	.028512	.003024	.003456
							3	.046368	.005040	.005040
7	KOPPERS	OIL CITY, PA	41 29 30	079 43 20	14860	3	2	.028512	.003024	.006048
9	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	4	3	.057456	.006048	.012096
10	MOBIL OIL	BEAUMOUNT, TX	30 04 14	094 03 40	12917	4	3	.019152	.002016	.004032
11	FMC	NITRO, WV	38 25 33	081 50 05	13866	5	4	.031824	.004608	.009072
12	STAUFFER	GALLIPOLIS FY, WV	38 46 40	082 10 54	13866	5	4	.025056	.002448	.005040

[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 10-34. (Concluded)

---

* Plant Types:

Type 1: Plant produces isolated p-cresol
Type 2: Plant produces mixed cresols and cresylic acid
Type 3: Plant produces mixed cresols
Type 4: Plant produces cresylic acid
Type 5: Plant produces tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP)

† Source Types:

Type 1: p-cresol production
Type 2: Mixed cresols production
Type 3: Cresylic acid production
Type 4: Tricresyl phosphate (TCP) and cresyl diphenyl phosphate (CDP) production

TABLE 10-35. EXPOSURE AND DOSAGE OF p-CRESOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (μg/m³)	Population Exposed (persons)	Dosage [(μg/m³) · persons]
10	57	682
5	631	4,780
2.5	2,847	12,300
1	10,133	22,300
0.5	32,841	37,600
0.25	78,175	52,800
0.1	299,683	86,100
0.05	801,086	120,000
0.025	1,627,372	150,000
0.01	3,066,093	174,000
5.6×10^{-5}*	10,438,324	187,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 10-36. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF p-CRESOL

Region	Resins Production		Wire Enamel Solvent		Pesticide Production		Ore Flotation		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of-Sites
New England	0.00681	6	0.0577	46	0.00039	4	0.0242	6	0.158	0
Middle Atlantic	0.00681	26	0.0577	339	0.00039	37	0.0242	38	0.158	15
East North Central	0.00681	31	0.0577	370	0.00039	19	0.0242	85	0.158	25
West North Central	0.00681	5	0.0577	84	0.00039	15	0.0242	145	0.158	3
South Atlantic	0.00681	15	0.0577	174	0.00039	17	0.0242	62	0.158	4
East South Central	0.00681	6	0.0577	44	0.00039	14	0.0242	40	0.158	9
West South Central	0.00681	11	0.0577	87	0.00039	15	0.0242	21	0.158	2
Mountain	0.00681	1	0.0577	258	0.00039	5	0.0242	144	0.158	2
Pacific	0.00681	24	0.0577	174	0.00039	13	0.0242	22	0.158	1

TABLE 10-37. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF p-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)						Dosage [$10^3(\mu g/m^3) \cdot$ persons]					
	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total	Resins Production	Wire Enamel Solvent	Pesticide Production	Ore Floatation	Coke Oven	U.S. Total
5	0	0	0	0	3.5	3.5	0	0	0	0	23	23
2.5	0	19	0	0	15	33	0	65	0	0	61	125
1	0	254	0	3	54	310	0	404	0	0	122	529
0.5	0	822	0	26	142	991	0	798	0	3	182	999
0.25	0	2,170	0	110	335	2,610	0	1,240	0	18	250	1,540
0.1	3.7	6,560	0	351	1,150	8,060	0.5	1,900	0	46	381	2,360
0.05	--	--	--	--	--	--	2.1	2,660	0	83	490	3,270
0.025	--	--	--	--	--	--	5.8	3,530	0	116	501	4,280
0.01	--	--	--	--	--	--	11.5	4,570	0.2	156	732	5,550
0	--	--	--	--	--	--	70.3	8,780	6	229	1,060	10,600

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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TABLE 10-38. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF p-CRESOL

Parameter	Value
Daytime decay rate (K_d)	1.41×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	1.0×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	13.683 gm/sec
Cleaning solvent	13.651 gm/sec
Miscellaneous	0.032 gm/sec
National mobile source emissions (E_M)	0

TABLE 10-39. p-CRESOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.050000	505140	35930.9	0.	100.0	0.	100.0	0.	0.
.025000	505140	35930.9	0.	100.0	0.	100.0	0.	0.
.010000	19790740	366437.1	0.	100.0	0.	100.0	0.	0.
.005000	44443179	533543.4	0.	100.0	0.	98.0	.4	1.6
.002500	111931566	766690.9	0.	100.0	0.	95.3	2.2	2.5
.001000	151902934	839614.3	0.	100.0	0.	92.3	2.9	4.8
0.	158679135	843949.7	0.	100.0	0.	91.9	2.9	5.2

TABLE 10-40. EXPOSURE AND DOSAGE SUMMARY OF p-CRESOL

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
10	57	0	0	57	682	0	0	682
5	631	3,500	0	4,131	4,780	23,000	0	27,780
2.5	2,847	33,000	0	35,847	12,300	125,000	0	137,300
1	10,133	310,000	0	320,133	22,300	529,000	0	531,300
0.5	32,841	991,000	0	1,024,000	37,600	999,000	0	1,036,600
0.25	78,175	2,610,000	0	2,688,000	52,800	1,540,000	0	1,592,800
0.1	299,683	8,060,000	0	8,359,683	86,100	2,360,000	0	2,446,100
0.05	801,086	--	505,140	---	120,000	3,270,000	35,931	---
0.025	1,627,372	--	505,140	---	150,000	4,280,000	35,931	---
0.01	3,066,093	--	19,790,740	---	174,000	5,550,000	366,437	---
0.005	---	--	44,443,179	---	---	--	533,543	---
0.0025	---	--	111,931,566	---	---	--	766,691	---
0.001	---	--	151,902,934	---	---	--	839,614	---
0	10,438,324	--	158,679,135	158,679,135	197,000	10,600,000	843,950	10,797,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-11 ----- Dimethylnitrosamine

For an explanation of the assumptions used to make these exposure estimates, please refer to the discussion beginning on page 57 of the report.

DIMETHYLAMINE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 124-40-3

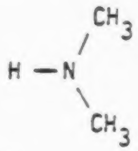
Synonyms: N-Methylmethanamine, DMA

Chemical Formula

Molecular Weight: 45.08

Molecular Formula: C_2H_7N

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Gas

Boiling Point: 7.4°C

Melting Point: -93°C

Density: 0.68 at 0°C/4°C

Vapor Pressure: 1290 mm at 25°C

Vapor Density: 1.55

Solubility: Infinitely soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): -0.38

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Methylamines are produced by the vapor phase ammonolysis of methanol. Monomethylamine, with smaller quantities of both dimethylamine and trimethylamine, is produced by passing methanol and ammonia over a dehydrating catalyst such as alumina and aluminum silicate. Separation of the methylamines into mono-, di-, and trimethylamine can be accomplished by a series of stage distillations or by extractive distillation. Dimethylamine is separated from a mixture of methylamines by subjecting the mixture to extractive distillation using aniline, morpholine, dimethylformamide or diethanolamine, in which dimethylamine is the most soluble. The dimethylamine is recovered by flashing from the solvent.

There are currently five producers of dimethylamine in the United States. The plant locations and the 1978 estimated capacity and production levels for each site are shown in Table 11-1. Production levels for each site were estimated from the total methylamine capacities of each site and the overall industry ratio of dimethylamines to total methylamines. An estimated 71.8 million lb of dimethylamine was produced in 1978.

B. USES

The end-use distribution of dimethylamine is shown in Table 11-2. An estimated 50% (35.9 million lb) of the dimethylamine produced is used to make the industrial solvents dimethyl formamide and dimethy acetamide. Approximately 15% (10.8 million lb) is used to make lauryl dimethylamine oxide, and 15% is used to make chemical accelerators for the rubber industry. Other uses of dimethylamine, accounting for the remaining 20% of production, are in pesticides manufacture and the dimethyl hydrazine used in rocket fuel.

Source locations of the manufacturers of dimethyl formamide, dimethyl acetamide, lauryl dimethylamine oxide, and dimethyl hydrazine are shown in Tables 11-3, 11-4 and 11-5.

Table 11-1. Dimethylamine Producers[a]

Company	Location	1978 Capacity[b] (10^6 lb/yr)	1978 Production[c] (10^6 lb/yr)	Geographic Location Latitude/Longitude
Air Products and Chemicals	Pensacola, FL	100	22.2	30 36 29/81 08 12
Du Pont	Belle, WV	165	36.7	38 13 06/81 34 12
	LaPorte, TX	20	4.5	29 42 04/95 02 05
GAF Corporation	Calvert City, KY	10	2.2	37 02 50/88 21 12
International Minerals & Chemical Corporation	Terre Haute, IN	28	6.2	39 27 07/87 25 02
Total		323	71.8	

[a] See refs. 1 and 2.

[b] Includes capacity for mono-, di-, and trimethylamines. Capacities are reduced significantly by recycling for a desired amine.

[c] Based on the ratio of total industry dimethylamine production to the total industry methylamines capacity X individual site methylamines capacity.

Table 11-2. Dimethylamine End-Use Distribution 1978*

Use	Usage (10^6 lb/yr)	Usage (%)
Dimethyl formamide and acetamide	35.9	50
Lauryl dimethylamine oxide	10.8	15
Rubber chemical accelerators	10.8	15
Pesticides and dimethyl hydrazine	14.3	20
Total	71.8	100

*See ref. 1.

Table 11-3. Dimethylamine Users for Dimethyl Formamide and Acetamide[a]

Company	Location	1978 Dimethylamine Usage (10^6 lb/yr)[b]	Geographic Location Latitude/Longitude
Air Products and Chemicals[c]	Pensacola, FL	12.0	30 36 29/81 08 12
Du Pont[d]	Belle, WV	12.0	38 13 06/81 34 12
Lachat Chemical, Inc.[c]	Mequon, WI	11.9	43 13 56/88 02 30
Total		35.9	

[a] See ref. 1.

[b] Total usage distributed evenly over all three sites.

[c] Dimethyl formamide.

[d] Dimethyl formamide and dimethyl acetamide.

Table 11-4. Dimethylamine Users for Lauryl Dimethylamine Oxide[a]

Company	Location	1978 Dimethylamine Usage[b] (10^6 lb/yr)	Geographic Location Latitude/Longitude
Akzona Inc.	McCook, IL	1.8	41 48 17/87 49 41
	Morris, IL	1.8	41 24 28/88 18 10
Continental Chemical	Clifton, NJ	1.8	40 43 34/74 07 26
Gulf Oil	Jersey City, NJ	1.8	40 43 02/74 06 10
Lonza, Inc.	Mapleton, IL	1.8	40 34 00/89 43 01
Scher Brothers, Inc.	Clifton, NJ	1.8	40 42 14/74 10 17
Total		10.8	

[a] See ref. 1.

[b] Total usage distributed evenly over all six sites.

Table 11-5. Dimethylamine User for Dimethyl Hydrazine[a]

Company	Location	1978 Dimethylamine[b] Usage (Million lb)	Geographic Location Latitude/Longitude
Teledyne McCormick Selph	Hollister, CA	7.15	36 50 06/121 25 00

[a] See refs. 1 and 3.

[b] Usage assumed to be ½ of 14.3 million lb.

II. EMISSION ESTIMATES

A. PRODUCTION

Estimated production losses are shown in Table 11-6 for each of the five producing locations. Total emissions of dimethylamine from production facilities are estimated to have been 143,600 lb in 1978. Process emissions originate primarily through condenser vents from the distillation columns. Other associated emission components include methanol, monomethylamine, trimethylamine, and ammonia. Storage emissions represent the total losses from crude and final product storage tanks and from loading and handling. Fugitive emissions are those which result from plant equipment leaks.

Vent stack data are shown in Table 11-7 for both production and enduse sources.

B. USES

Total emissions of dimethylamine resulting from its use as a chemical intermediate are estimated to have been 71,800 lb in 1978 using an emission factor of 0.001 lb lost/lb produced. This factor was determined from dimethylamine use in 2-4-D manufacturing and is considered representative of its use as a chemical intermediate. Vent parameter data for chemical intermediate end-use are shown in Table 11-7.

Source locations of end-use emissions are shown in Table 11-8. Emissions for pesticide manufacturing and rubber accelerators are shown by region in Tables 11-9 and 10. The total nationwide emissions of dimethylamine in 1978 from all sources is shown in Table 11-11 and is estimated to have been 215,400 lb.

Table 11-6. Dimethylamine Production Emissions

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Air Products and Chemicals	Pensacola, FL	28,860	4,440	11,100	44,400	0.64
Du Pont	Belle, WV	47,710	7,340	18,350	73,400	1.06
	Laporte, TX	5,850	900	2,250	9,000	1.30
GAF Corporation	Calvert City, KY	2,860	440	1,100	4,400	0.06
International Minerals	Terre Haute, IN	8,060	1,240	3,100	12,400	0.18
Total		93,340	14,360	35,900	143,600	

[a] Based on the following emission factor (lb dimethylamine lost per lb produced). See ref. 4.

Process	0.0013	C-Published source
Storage	0.0002	C-Published source
Fugitive	0.0005	C-Published source
Total	0.0020	

[b] Assuming 8760 hr/yr operation.

Table 11-7. Dimethylamine Vent Parameters

	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[a,b]					
Process	2	40	0.17	130	22
Storage	8	20	0.17	80	
End-uses[a,b]					
Process	1	30	0.17	100	15
Storage	2	20	0.17	80	

[a] Fugitive emissions distributed over a 300 ft X 300 ft area.

[b] Building cross-section 100 m^2.

Table 11-8. Emissions from Dimethylamine Users

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Air Products	Pensacola, FL	7,800	1,200	3,000	12,000	0.173
Du Pont	Belle, WV	7,800	1,200	3,000	12,000	0.173
Lachat	Mequon, WI	7,735	1,190	2,975	11,900	0.171
Akzona	McCook, IL	1,170	180	450	1,800	0.026
	Morris, IL	1,170	180	450	1,800	0.026
Continental	Clifton, NJ	1,170	180	450	1,800	0.026
Gulf Oil	Jersey City, NJ	1,170	180	450	1,800	0.026
Lonza	Mapleton, IL	1,170	180	450	1,800	0.026
Scher Brothers	Clifton, NJ	1,170	180	450	1,800	0.026
Teldyne McCormick Selph	Hollister, CA	4,648	715	1,787	7,150	0.103
Total		35,003	5,385	13,462	53,850	

[a] Emission factor dimethylamine (lb lost per lb used). See ref. 4.

Process	0.00065	C-Published source
Storage	0.00010	C-Published source
Fugitive	0.00025	C-Published source
Total	0.00100	

[b] Assumes 8760 hr/yr operation.

Table 11-9. 1978 Dimethylamine Emission Estimate from Pesticide Manufacturers[a]

Region	Number of Sites per Region	Dimethylamine Emissions[b] (lb/yr)	Dimethylamine Emissions[b] (g/sec)[c]
New England	4	206	0.003
Middle Atlantic	37	1903	0.027
East North Central	19	977	0.014
West North Central	15	772	0.011
South Atlantic	17	874	0.013
East South Central	14	720	0.010
West South Central	15	772	0.011
Mountain	5	257	0.004
Pacific	13	669	0.010
Total	139	7150	

[a] From refs. 1 and 3.

[b] Based on an average emission rate of 51.4 lb/yr per site.

[c] Based on 8760 hr/yr operation.

Table 11-10. 1978 Dimethylamine Emission Estimates from Rubber Chemical Accelerator Manufacturers[a]

		Dimethylamine Emissions[b]	
Region	Number of Sites per Region	(lb/yr)	(g/sec)[c]
New England	15	1,688	0.024
Middle Atlantic	24	2,700	0.039
East North Central	25	2,813	0.041
South Atlantic	9	1,012	0.015
East South Central	18	2,025	0.029
West South Central	5	562	0.008
Total	96	10,800	

[a] See refs. 1 and 3.

[b] Based on an average emission rate of 112.5 lb/yr per site.

[c] Based on 8760 hr/yr operation.

Table 11-11. 1978 Dimethylamine Nationwide Emissions

Source	Production/ Usage (10^6 lb/yr)	Usage (%)	Total Emissions (lb/yr)
Producers	71.8		143,600
Users			
DMF and DMA[a]	35.9	50	35,900
Lauryl DMA oxide[b]	10.8	15	10,800
Rubber chemical accelerators	10.8	15	10,800
Dimethyl hydrazine/pesticides	14.3	20	14,300
Total			215,400

[a] Dimethyl formamide and dimethyl acetamide (industrial solvents).

[b] Lauryl dimethylamine oxide.

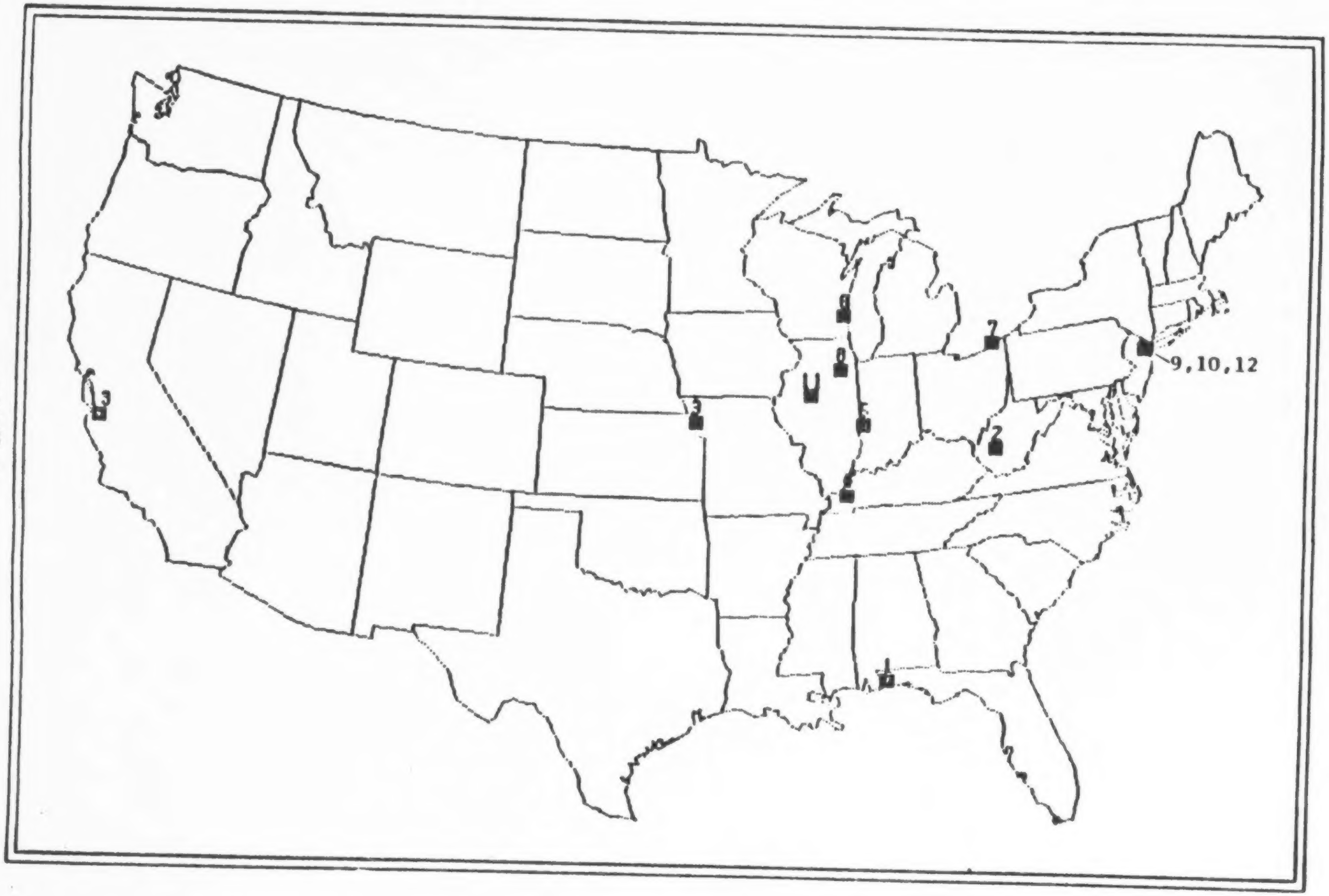

3
3
7
2
1
9,10,12

FIGURE 11-1. SPECIFIC POINT SOURCES OF DIMETHYLAMINE EMISSIONS

TABLE 11-12. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF DIMETHYLAMINE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	AIR PRODUCTS	PENSACOLA, FL	30 36 29	087 08 12	03855	1	1	.415584	.063936	.159840
							2	.112320	.017280	.043200
2	DUPONT	BELLE, WY	38 13 06	081 34 12	13866	1	1	.687024	.105696	.264240
							2	.112320	.017280	.043200
3	DUPONT	LAPORTE, TX	39 42 04	095 02 05	12906	2	1	.084240	.012960	.032400
4	CAF CORPORATION	CALVERT CITY, KY	37 02 50	088 21 12	03816	2	1	.041184	.006336	.015840
5	INTER MINERAL	TERRE HAUTE, IN	39 27 07	087 25 02	13806	2	1	.116064	.017856	.044640
6	LACHAT	MEQUOH, WI	43 13 56	088 02 30	14839	3	2	.111384	.017136	.042840
7	AKZONA	MCCOOK, IL	41 48 17	081 08 12	03855	3	2	.016848	.002592	.006480
8	AKZONA	MORRIS, IL	41 24 24	088 18 10	14855	3	2	.016848	.002592	.006480
9	CONTINENTAL	CLIFTON, NJ	40 43 34	074 07 26	94741	3	2	.016848	.002592	.006480
10	GULF OIL	JERSEY CITY, NJ	40 43 02	074 06 14	94741	3	2	.016848	.002592	.006480
11	LONZA	MAPLETON, IL	40 34 00	089 43 01	14842	3	2	.016848	.002592	.006480
12	SCHER BROTHERS	CLIFTON, NJ	40 42 14	074 10 17	94741	3	2	.016848	.002592	.006480
13	TELDYNE MCCORMI	HOLLISTER, CA	36 50 06	121 25 00	23199	3	2	.066931	.010296	.025733

TABLE 11-12. (Concluded)

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* Plant Types:

Type 1: Plant produces dimethylamine and uses it to produce dimethyl formamide (DMF)/dimethyl acetamide (DMA)

Type 2: Plant produces dimethylamine

Type 3: Plant produces dimethyl formaldehyde (DMF), dimethyl acetamide (DMA), lauryl dimethylamine oxide, or dimethyl hydrazine

† Source Types:

Type 1: Dimethylamine

Type 2: Dimethylamine consumption

TABLE 11-13. EXPOSURE AND DOSAGE OF DIMETHYLNITROSAMINE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
0.01	4	.0418
0.005	112	.704
0.0025	1,437	4.78
0.001	14,843	22
0.0005	65,125	56.9
0.00025	261,935	127
0.0001	395,198	149
0.00005	974,464	185
0.000025	3,569,282	266
0.00001	15,127,027	450
1.34×10^{-6}*	18,661,392	470

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 11-14. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF DIMETHYLAMINE

Region	Pesticide Production		Chemical Accelerator	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00074	4	0.00162	15
Middle Atlantic	0.00074	37	0.00162	24
East North Central	0.00074	19	0.00162	25
West North Central	0.00074	15	0	0
South Atlantic	0.00074	17	0.00162	9
East South Central	0.00074	14	0.00162	18
West South Central	0.00074	15	0.00162	5
Mountain	0.00074	5	0	0
Pacific	0.00074	13	0	0

TABLE 11-15. **DIMETHYLNITROSAMINE EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF DIMETHYLAMINE**

Concentration Level (ng/m^3)	Population Exposed (10^3 persons)			Dosage [$10^3(ng/m^3)\cdot persons$)		
	Pesticide Production	Chemical Accelerator	U.S. Total	Pesticide Production	Chemical Accelerator	U.S. Total
0.025	0	0.16	0.16	0	0.005	0.005
0.010	0.6	13.1	13.8	0.008	0.183	0.191
0.0050	12	136	148	0.078	0.987	1.06
0.0025	--	--	--	0.45	4.53	4.98
0.0010	--	--	--	3.18	30.8	34.0
0.0005	--	--	--	14.3	56.9	71.2
0.00025	--	--	--	30.5	76.9	107
0	--	--	--	57.2	90.3	148

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 11-16. EXPOSURE AND DOSAGE SUMMARY OF DIMETHYLNITROSAMINE

Concentration Level (μg/m^3)	Population Exposed (persons)				Dosage [(μg/m^3)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
0.01	4	0	0	4	.0418	0	0	.0418
0.005	112	0	0	112	1	0	0	1
0.0025	1,437	0	0	1,437	5	0	0	5
0.001	14,843	0	0	14,843	22	0	0	22
0.0005	65,125	0	0	65,125	57	0	0	57
0.00025	261,935	0	0	261,935	127	0	0	127
0.0001	395,198	0	0	395,198	149	0	0	149
0.00005	974,464	0	0	974,464	185	0	0	185
0.000025	3,569,282	0	0	3,569,282	266	0	0	266
0.00001	15,127,027	13,800	0	15,140,827	450	0	0	450
0.000005	--	148,000	0	--	--	1	0	--
0.0000025	--	--	0	--	--	5	0	--
0.000001	--	--	0	--	--	34	0	--
0	18,661,592	--	0	--	470	148	0	618

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. T. F. Killilea, "Miscellaneous Aliphatic Amines," p. 611.5030B, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (July 1978).

2. "Miscellaneous Aliphatic Amines——Salient Statistics," Chemical Economics Handbook, Manual of Current Indicators——Supplemental, Stanford Research Institute, Menlo Park, CA (April 1979).

3. Directory of Chemical Producers in the United States, 1978, pp. 564, 567 and 931, Stanford Research Institute, Menlo Park, CA.

4. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, OH, by Monsanto Research Corporation, Dayton, OH (April 1976).

SUPPLEMENTAL SHEET FOR DIOXIN

Attachment A-12-1

As a result of information received subsequent to the original distribution of this document, the following are noted:

- Dioxin emission estimates in this document are theoretical. Testing of at least one plant (Vulcan Chemical, Wichita, Kansas) has shown no evidence of either emissions of dioxin or dioxin in the product. Additional assessment of all sources is planned by EPA.

- The Monsanto plant identified in Table 12-3 no longer produces pentachlorophenol.

APPENDIX A-12-2 ----- Dioxin

DIOXIN CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 1746-01-6

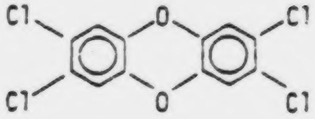
Synonyms: 2.3.7.8 - Tetrachlorodibenzo-p-dioxin; 2.3.7.8-TCDD

Chemical Formula

Molecular Weight: 251

Molecular Formula: $C_{12}H_4Cl_4O_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid - Colorless needles

Boiling Point:

Melting Point: 306°C

Density:

Vapor Pressure:

Vapor Density:

Solubility: Insoluble (2×10^{-7} g/l of H_2O

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) is only one of a total of 75 compounds that make up a group of chemicals referred to as polychlorinated dioxin. It is an impurity that results from the manufacture of trichlorophenol which is used to make 2,4,5-trichlorophenoxy acetic acid, commonly referred to as 2,4,5-T, a herbicide. The primary end-use for 2,4,5-T is for weed and grass control.[1]

2,3,7,8-TCDD has also been reported in pentachlorophenol which is produced by chlorinating phenol or polychlorophenols.[2] The primary end-use for pentachlorophenol is as a wood preservative.

An estimated 6.5 million lb of 2,4,5-T was produced and consumed as weed killer in the United States in 1978.[3] Table 12-1[4] lists the five companies at seven locations that produced 2,4,5-T.

An estimated 10 million lb of trichlorophenol was produced by two companies at two locations as shown in Table 12-2.[4]

Pentachlorophenol production was estimated to have been 47 million lb in 1978. Producers and site locations are identified in Table 12-3.[2]

In addition to its formation in the chlorinated chemical reactions noted above, Dow Chemical announced, in late 1978, findings that indicate 2,3,7,8-TCDD is a product of fire chemistry.[5] Dow claims that 2,3,7,8-TCDD is created during the burning of organic material and can be found in the resulting particulate matter emitted. Dow tests found traces of 2,3,7,8-TCDD in the emissions of gasoline and diesel engines, incinerators, powerhouse boiler stacks, fireplaces, and cigarettes ranging from 0.001 to 1100 ppb.[5]

II. EMISSION ESTIMATES

Prior to 1965 2,3,7,8-TCDD was present in concentrations of up to 50 ppm in 2,4,5-T. Since then, sufficient technology became available to allow the manufacture of 2,4,5-T containing no more than 1 ppm 2,3,7,8-TCDD.[1]

Table 12-1. 2,4,5-T (Trichlorophenoxyl Acetic Acid) Producers[a]

Company	Location	2,4,5-T Capacity (million lb/yr)	2,4,5-T Production (million lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	NA[c]	0.93	43 25 28/84 13 08
PBI-Gordon	Kansas City, KA	NA	0.93	39 08 53/94 40 59
Riverdale	Chicago Heights, IL	NA	0.93	41 30 30/87 38 11
Union Carbide	Ambler, PA	NA	0.93	40 01 48/75 13 41
	Fremont, CA	NA	0.93	37 28 38/122 00 40
	St. Joseph, MO	NA	0.93	39 45 36/94 50 46
Vertac	Jacksonville, AR	NA	0.93	34 55 36/92 04 56
Total		NA	6.5	

---

[a] See ref. 4.

[b] Production evenly distributed over all sites in the absence of capacity data.

[c] Not available.

Table 12-2. Trichlorophenol Producers[a]

Company	Location	Trichlorophenol Capacity (million lb/yr)	Trichlorophenol Production (million lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	NA[c]	5	43 25 28/84 13 08
Vertac	Jacksonville, AR	NA	5	34 55 36/92 04 46
Total		NA	10[d]	

---

[a] See ref. 4.

[b] Production split between both sites.

[c] Not available.

[d] Hydroscience estimate.

Table 12-3. Pentachlorophenol Producers[a]

Company	Location	Pentachlorophenol Capacity (million lb/yr)	Pentachlorophenol Production (million lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Dow	Midland, MI	15	10	43 25 28/84 13 08
Monsanto	Sauget, IL	26	18	38 35 31/90 10 11
Reichhold	Tacoma, WA	12	8	47 16 11/122 22 57
Vulcan	Wichita, KA	16	11	37 36 55/97 18 30
Total		69	47	

[a] See ref. 2.

[b] Total pentachlorophenol distributed by site capacity.

Emissions for chemical producers were estimated by assuming that 0.005 lb of product was lost per lb of product produced and the 2,3,7,8-TCDD concentration in the production emission was 50 ppm, i.e., the maximum level reported in 2,4,5-T prior to 1965.[1]

Total emissions of 2,3,7,8-TCDD from the processes producing 2,4,5-T, trichlorophenol and pentachlorophenol were 1,6, 2.5, and 11.8 lb respectively. An additional 6.5 lb of 2,3,7,8-TCDD is lost each year when 2,4,5-T is applied to land for weed control, and pentachlorophenol emissions from its use as a wood preservative (90% of production) have the potential of releasing 42.3 lb/yr assuming 2,3,7,8-TCDD concentrations of 1 ppm in both cases.[1]

Using an average concentration from Dow data of 2 ppb 2,3,7,8-TCDD in burned particulate matter and the particulate emission estimates made by Mitre[6] as shown in Table 12-4,2,3,7,8-TCDD emissions from burning were estimated at 18.8 lb/yr.

Total emissions of 2,3,7,8-TCDD from all sources were estimated to have been 83.5 lb in 1978. Table 12-5 summarizes 2,3,7,8-TCDD emissions.

Table 12-4. Potential Sources of 2,3,7,8-TCDD (Emissions of Particulates) from Burning

Source	Particulate Emissions (tons/yr)[a]	Total Emissions (lb/yr)[b]
Open burning		
Agriculture	2,161,142	8.6
Forest fires	1,433,712	5.7
Refuse open burning	526,843	2.1
Conical burners	212,211	0.8
	193,500	0.8
Coal burning——all sources	108,952	0.4
Oil burning——all sources	72,389	0.3
Incineration, municipal domestic	30,123	0.1
Total		18.8

[a] See ref. 6.

[b] Based on an emission concentration of the particulate of 2 ppb (see ref. 5).

Table 12-5. 1978 Total Nationwide Emission Estimates of 2,3,7,8-TCDD

Source	Nationwide Emissions (lb/yr)
Trichlorophenol production	2.5
2,4,5-T production	1.6
Pentachlorophenol production	11.8
Burning (fire sources)	18.8
2,4,5-T application (use)	6.5
Pentachlorophenol as wood preservative (use)	42.3
Total	83.5

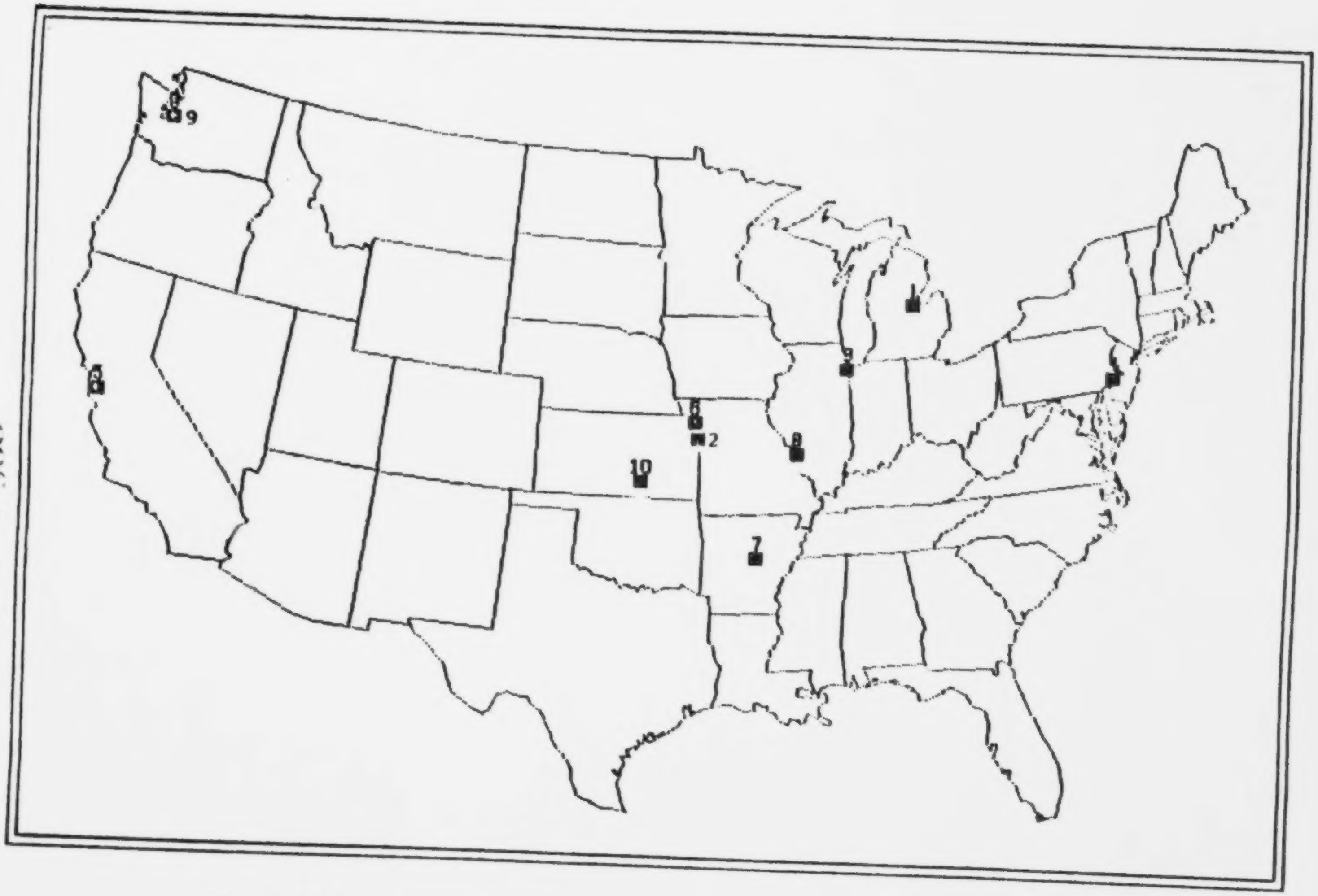


FIGURE 12-1. SPECIFIC POINT SOURCES OF 2,3,7,8-TCDD EMISSIONS

TABLE 12-6. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF 2,3,7,8-TCDD

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (MG/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	1	1 2 3	0. 0. 0.	0. 0. 0.	.003298 .018000 .042480
2	PBI-GORDON	KANSAS CITY, KA	39 08 53	094 40 59	13988	2	1	0.	0.	.003298
3	RIVERDALE	CHICAGO HEIGHTS, IL	41 30 30	087 38 11	94846	2	1	0.	0.	.003298
4	UNION CARBIDE	AMBLER, PA	40 01 48	075 13 41	13739	2	1	0.	0.	.003298
5	UNION CARBIDE	FREMONT, CA	37 28 38	122 00 40	23244	2	1	0.	0.	.003298
6	UNION CARBIDE	ST. JOSEPH, MO	39 45 36	094 50 46	13921	2	1	0.	0.	.003298
7	VERTAC	JACKSONVILLE, AR	34 55 36	092 04 56	13963	3	1 2	0. 0.	0. 0.	.003298 .018000
8	MONSANTO	SAUGET, IL	38 35 31	090 10 11	13994	4	3	0.	0.	.042480
9	REICHHOLD	TACOMA, WA	47 16 11	122 22 57	24207	4	3	0.	0.	.042480
10	VULCAN	WICHITA, KA	37 36 55	097 18 30	03928	4	3	0.	0.	.042480

TABLE 12-6. (Concluded)

---

* Plant Types:

Type 1: Plant produces 2,4,5-T, trichlorophenol, and pentachlorophenol
Type 2: Plant produces 2,4,5-T
Type 3: Plant produces 2,4,5-T and trichlorophenol
Type 4: Plant produces pentachlorophenol

† Source Types:

Type 1: 2,4,5-T production
Type 2: Trichlorophenol production
Type 3: Pentachlorophenol production

TABLE 12-7. EXPOSURE AND DOSAGE OF 2, 3, 7, 8-TCDD RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
2.5	1	3
1	12	18
0.5	57	48
0.25	151	80
0.1	550	139
0.05	3,249	326
0.025	11,006	578
0.01	33,516	925
0.005	106,892	1,430
0.0025	306,516	2,110
0.001	1,048,267	3,250
0.0005	1,938,136	3,890
5.5×10^{-6}*	7,765,165	4,470

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 12-8. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF 2,3,7,8-TCDD (DIOXIN)

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	9.734×10^{-4} mg/sec
2,4,5-T application	9.36×10^{-5} mg/sec
Wood preservative	6.091×10^{-4} mg/sec
Burning	2.707×10^{-4} mg/sec
Nationwide mobile source emissions (E_M)	0

TABLE 12-9. 2,3,7,8-TCDD EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.005000	446952	2373.2	0.	100.0	0.	100.0	0.	0.
.002500	505140	2622.0	0.	100.0	0.	100.0	0.	0.
.001000	14890505	26247.1	0.	100.0	0.	100.0	0.	0.
.000500	35729915	41054.4	0.	100.0	0.	100.0	0.	0.
.000250	92471736	60521.2	0.	100.0	0.	97.5	1.1	1.4
.000100	145894185	70028.4	0.	100.0	0.	93.8	2.5	3.7
0.	158679135	70894.0	0.	100.0	0.	92.9	2.6	4.5

TABLE 12-10. EXPOSURE AND DOSAGE SUMMARY OF 2, 3, 7, 8-TCDD (DIOXIN)

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
2.5	1	0	0	1	3	0	0	3
1	12	0	0	12	18	0	0	18
0.5	57	0	0	57	48	0	0	48
0.25	151	0	0	151	80	0	0	80
0.1	550	0	0	550	139	0	0	139
0.05	3,249	0	0	3,249	329	0	0	329
0.25	11,006	0	0	11,006	578	0	0	578
0.01	33,516	0	0	33,516	925	0	0	925
0.005	106,892	0	446,952	--	1,430	0	2,373	3,803
0.0025	306,516	0	505,140	--	2,110	0	2,622	4,738
0.001	1,048,267	0	14,890,505	--	3,250	0	26,247	29,497
0.0005	1,938,136	0	35,729,915	--	3,890	0	41,054	45,944
0.00025	--	0	92,471,736	--	--	0	60,521	--
0.0001	--	0	145,894,185	--	--	0	70,028	--
0	7,765,165	0	158,679,135	--	4,470	0	70,894	74,574

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. Report on 2,4,5-T, A report of the panel on herbicides of the President's Science Advisory Committee, Executive Office of the President, Office of Science and Technology (March 1971).

2. "Chemical Product Synopsis on Pentachlorophenol," Mannsville Chemical Products, Mannsville, NY (September 1977).

3. "Herbicides," Chemical Economics Handbook, p. 573.7000A—70060, Stanford Research Institute, Menlo Park, CA (December 1976).

4. 1979 Directory of Chemical Producers, United States, Stanford Research Institute, Menlo Park, CA.

5. The Trace Chemistries of Fire——A Source of and Routes for the Entry of Chlorinated Dioxins into the Environment, the Chlorinated Dioxin Task Force, The Michigan Division, Dow Chemical U.S.A (November 1978).

6. A Survey of Emissions and Controls for Hazardous and Other Pollutants by Mitre for EPA (February 1973).

APPENDIX A-13 ----- Epichlorohydrin

EPICHLOROHYDRIN CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 106-89-8

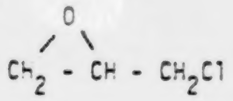
Synonyms: 3-Chloro-1,2-Propylene; 3-Chloro-1-Ozacyclobutane; 3-Chlorooxetane; Chloromethyloxirane; dl-α-Epichlorohydrin; 1-Chloro-2,3-Epoxypropane; γ-Chloropropylene Oxide

Chemical Formula

Molecular Weight: 92.53

Molecular Formula: C_3H_5ClO

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless

Boiling Point: 117.9°C

Melting Point: -25.6°C

Density: 1.1801 at 20°C/4°C

Vapor Pressure: 16.8 mm at 25°C

Vapor Density: 3.29

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors: N/A

Formation Reactivity:

A.

I. SOURCES

All allyl chloride currently produced in the United States by the chlorination of propylene is consumed in the production of epichlorohydrin.[1,2] Allyl chloride is first reacted with hypochlorous acid to form dichlorohydrin; dichlorohydrin is then reacted with sodium hydroxide or calcium hydroxide to form crude epichlorohydrin.[2]

Crude epichlorohydrin can be used directly for the production of synthetic glycerin.[2] For other end-uses (primarily epoxy resins) the crude product is further refined by distillation.[2]

Allyl chloride and epichlorohydrin are both produced by two companies at three locations.[2] The plant locations and the 1978 capacities and estimated production levels for each plant are shown in Table 13-1.[1,2] The estimated quantities of allyl chloride and epichlorohydrin produced in 1978 were 330 million lb and 312 million lb respectively.[2]

The primary end-uses of epichlorohydrin are for the manufacture of epoxy resins and synthetic glycerin. An estimated 53% of epichlorohydrin production amounting to 165 million lb was consumed to produce epoxy resins and 25%, or 78 million lb, was consumed in the manufacture of synthetic glycerin.[1,2]

Most of the other applications of epichlorohydrin are relatively minor. Epichlorohydrin elastomers consumed an estimated 6 million lb (2%) in 1978. An estimated 47 million lb (15%) was used to produce a variety of products in relatively small volume including glycidol ethers, some types of modified epoxy resins, wet strength resins for the paper industry, water treatment resins, surfactants, and ion-exchange resins. Exports of epichlorohydrin are estimated to have been 16 million lb (5%)in 1978. End-uses are summarized in Table 13-2.[1,2] Specific source locations of the epoxy resin producers are shown in Table 13-3.[1,2]

EMISSIONS ESTIMATES

1. Production

Estimated production losses are shown in Table 13-4 for each of the three producing locations. Total emissions of allyl chloride and epichlorohydrin from production facilities are estimated to have been 1,112,100 lb and 146,640 lb respectively in 1978.[3] Process emissions originate primarily through the condenser vents from the distillation columns.[3] Other associated emissions include C_3 hydro-

Table 13-1. Production of Allyl Chloride, Epichlorohydrin, and Acrolein[a]

Source	Location	1978 Estimated Production[b] (M lb) Allyl Chloride	1978 Estimated Production[b] (M lb) Epichlorohydrin	1978 Estimated Production[b] (M lb) Acrolein	1978 Estimated Capacity (M lb) Allyl Chloride	1978 Estimated Capacity (M lb) Epichlorohydrin	1978 Estimated Capacity (M lb) Acrolein	Geographic Coordinates Latitude/Longitude
Dow Chemical Co.	Freeport, TX	176	166		265	250		28 59 30/95 23 35
Shell Chemical Co.	Deer Park, TX	77	73		117	110		29 42 55/95 07 34
Shell Chemical Co.	Norco, LA	77	73	24[c]	117	110	55[c]	30 00 11/90 23 42
Union Carbide Corp.	Taft, La			22[c]			60[c]	29 58 00/90 27 00
Celanese Corp.	Clear Lake, TX			89[d]			167[d]	29 37 17/95 03 51
Rohm and Haas Co.	Deer Park, TX			146[d]			273[d]	29 43 30/95 06 15
Union Carbide Corp.	Taft, LA			73[d]			137[d]	29 58 00/90 27 00
Total		330	312	354	499	470	692	

---

[a] See refs 1 and 2.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

[c] Isolated acrolein.

[d] Acrolein produced as an unisolated intermediate in the propylene oxidation process for acrylic acid and derivitives.

Table 13-2. 1978 Epichlorohydrin Consumption by End-Use*

End-Use	Percent of Total Consumption	End-Use Consumption (M lb)
Glycerin	25	78
Unmodified epoxy resins	53	165
Miscellaneous products	15	47
Epichlorohydrin elastomers	2	6
Export	5	16
Total	100.0	312

*See refs 1 and 2.

Table 13-3. Users of Epichlorohydrin to Produce Epoxy Resins[a]

Company	Location	1978 Estimated Epoxy Resin Capacity (M lb)	1978 Estimated Epichlorohydrin[b] Used ($\bar{M}$ lb)	Geographic Coordinates Latitude/Longitude
Celanese	Linden, NJ	40	14	4035 10/74 13 40
	Louisville, KY	25	9	3812 23/85 52 09
Ciba-Geigy	Toms River, NJ	60	22	3959 20/74 22 33
Dow	Freeport, TX	170	61	28 59 15/95 24 45
Reichhold	Andover, MA	8[c]	3	42 08 30/71 08 28
	Azusa, CA	8[c]	3	34 07 52/117 53 51
	Detroit, MI	8[c]	3	4228 17/83 07 52
	Houston, TX	8[c]	3	29 45 10/95 10 15
Shell	Deer Park, TX	100	36	29 42 55/95 07 34
Union Carbide	Bound Brook, NJ	10	4	4033 32/74 31 18
	Taft, LA	20	7	29 58 00/90 27 00
Total		457	165	

[a] See refs. 1 and 2.

[b] Epichlorohydrin usage allocated to each site based on resin capacity.

[c] Reichhold's total epoxy resin capacity at 32 $\bar{M}$ lb allocated evenly over all four producing sites.

Table 13-4. 1978 Allyl Chloride and Epichlorohydrin Production Emissions

Company	Location	Process Emissions: Allyl Chloride (lb/yr)	Process Emissions: Epichlorohydrin (lb/yr)	Storage Emissions: Allyl Chloride (lb/yr)	Storage Emissions: Epichlorohydrin (lb/yr)	Fugitive Emissions: Allyl Chloride (lb/yr)	Fugitive Emissions: Epichlorohydrin (lb/yr)	Total Emissions: Allyl Chloride[a] (lb/yr)	Total Emissions: Allyl Chloride[a] (g/sec)[c]	Total Emissions: Epichlorohydrin[b] (lb/yr)	Total Emissions: Epichlorohydrin[b] (g/sec)[c]
Dow	Freeport, TX	515,680	69,720	24,640	1,660	52,800	6,640	593,120	8.54	78,020	1.12
Shell	Deer Park, TX	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
	Norco, LA	225,610	30,660	10,780	730	23,100	2,920	259,490	3.74	34,310	0.49
Total		966,900	131,040	46,200	3,120	99,000	12,480	1,112,100		146,640	

[a] Based on allyl chloride emission factor (lb lost/lb produced). See refs. 7—9.

Process	0.00293	B - From state files
Storage	0.00014	B - From state files
Fugitive	0.00030	D - Engineering estimate
Total	0.00337	

[b] Based on epichlorohydrin emission factor (lb lost/lb produced). See refs. 6, 8, and 9.

Process	0.00042	B - Fron state files
Storage	0.00001	B - From state files
Fugitive	0.00004	D - Engineering estimate
Total	0.00047	

[c] Based on 8760 hr/yr operation.

carbons and other C_3 chlorinated hydrocarbons.[3] Storage emissions, which represent total losses from storage tanks and loading and handling, are generally controlled by the use of pressurized tanks and/or refrigerated vent condensers and account for less than 5% of allyl chloride losses and less than 3% of epichlorohydrin losses.[6,7] Fugitive emissions are those which result from plant equipment leaks.

Vent stack data are shown in Table 13-5. Typically, there are four process vents that emit allyl chloride and three process vents that emit epichlorohydrin. Emissions from banks of storage tanks are normally collected and discharged from common vent stacks. Usually allyl chloride/epichlorohydrin production facilities are "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

2. Uses

For the purpose of this report, emissions resulting from the export of epichlorohydrin are assumed to be negligible.

Since the only significant end-use for allyl chloride is in the production of epichlorohydrin, allyl chloride end-use emissions are included in the allyl chloride/epichlorohydrin production emissions.

More than half (53%) of the epichlorohydrin produced is used in the production of epoxy resins. The current domestic producers of epoxy resins, plant locations, and estimated emissions of epichlorohydrin are given in Table 13-6. Vent parameter data relative to epichlorohydrin emissions from epoxy resin production are shown in Table 13-5.

Emissions of epichlorohydrin resulting from the production of glycerin, the next largest end-use of epichlorohydrin (25%), are included in the listed epichlorohydrin production emissions. (Glycerin and the required epichlorohydrin are produced at the same location.) Emissions resulting from the use of epichlorohydrin in the production of miscellaneous products were estimated by using the epoxy resin (epichlorohydrin use) emission factor. Specific source locations for miscellaneous chemical intermediate use could not be identified.

Total nationwide emissions of allyl chloride and epichlorohydrin in 1978 from all sources are estimated to have been 1.11 million lb and 0.479 million lb respectively. A tabulation of the losses is shown in Table 13-7.

Table 13-5. Allyl Chloride and Epichlorohydrin Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[a,b]					
Process vents					
Allyl chloride	2	85	0.6	80	Intermittent
	2	40	0.167	228	5.5
Epichlorohydrin	3	50	0.34	90	13.8
Storage vents					
Allyl chloride	2	15 - 20	0.6	86	
Epichlorohydrin	2	15 - 20	0.6	80	
Use[c,d]					
Epoxy resins, elastomers and misc. products					
Process					
Column vent	1	50	0.33	115	5.3
Recovery vents	3	135	0.83	110	10.0
Storage	7	20	0.17	80	

[a] Building cross-section 5 m^2.

[b] Fugitive emissions distributed over a 300 ft X 300 ft area.

[c] Building cross-section 100 m^2.

[d] Fugitive emissions distributed over a 100 ft X 200 ft area.

Table 13-6. 1978 Epichlorohydrin Emissions from Epoxy Resin Production

Company	Location	Process Emissions (lb/yr)	Process Emissions (g/sec)[b]	Storage Emissions (lb/yr)	Storage Emissions (g/sec)[b]	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)[b]	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Celanese	Linden, NJ	15,960	0.230	1,400	0.020	3,920	0.056	21,280	0.306
	Louisville, KY	10,260	0.148	900	0.013	2,520	0.036	13,680	0.197
Ciba-Geigy	Toms River, NJ	25,080	0.361	2,200	0.032	6,160	0.089	33,440	0.481
Dow	Freeport, TX	69,540	1.001	6,100	0.088	17,080	0.246	92,720	1.335
Reichhold	Andover, MA	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Azusa, CA	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Detroit, MI	3,420	0.049	300	0.003	840	0.012	4,560	0.066
	Houston, TX	3,420	0.049	300	0.003	840	0.012	4,560	0.066
Shell	Deer Park, TX	41,040	0.591	3,600	0.052	10,080	0.145	54,720	0.788
Union Carbide	Bound Brook, NJ	4,560	0.066	400	0.004	1,120	0.016	6,080	0.088
	Taft, LA	7,980	0.115	700	0.010	1,960	0.028	10,640	0.153
Total		188,100		16,500		46,200		250,800	

[a] Emission factor for epichlorohydrin emissions (lb lost per lb used). See ref. 10.

Process	0.00114	B - From state files
Storage	0.00010	B - From state files
Fugitive	0.00028	B - From state files
Total	0.00152	

[b] Assumes 8760 hr/yr operation.

Table 13-7. 1978 Estimated Allyl Chloride and Epichlorohydrin Nationwide Emission Losses

	Estimated National Emissions	
Source	Allyl Chloride (M lb/yr)	Epichlorohydrin (M lb/yr)
Production (allyl chloride, epichlorohydrin, and glycerin)	1.11	0.147
Unmodified epoxy resins - use		0.251
Chemical intermediate - use		0.081
Export	0	0
Total	1.11	0.479

*Based on emission factor of 0.00152 lb lost per lb used derived for epoxy resin manufacture.

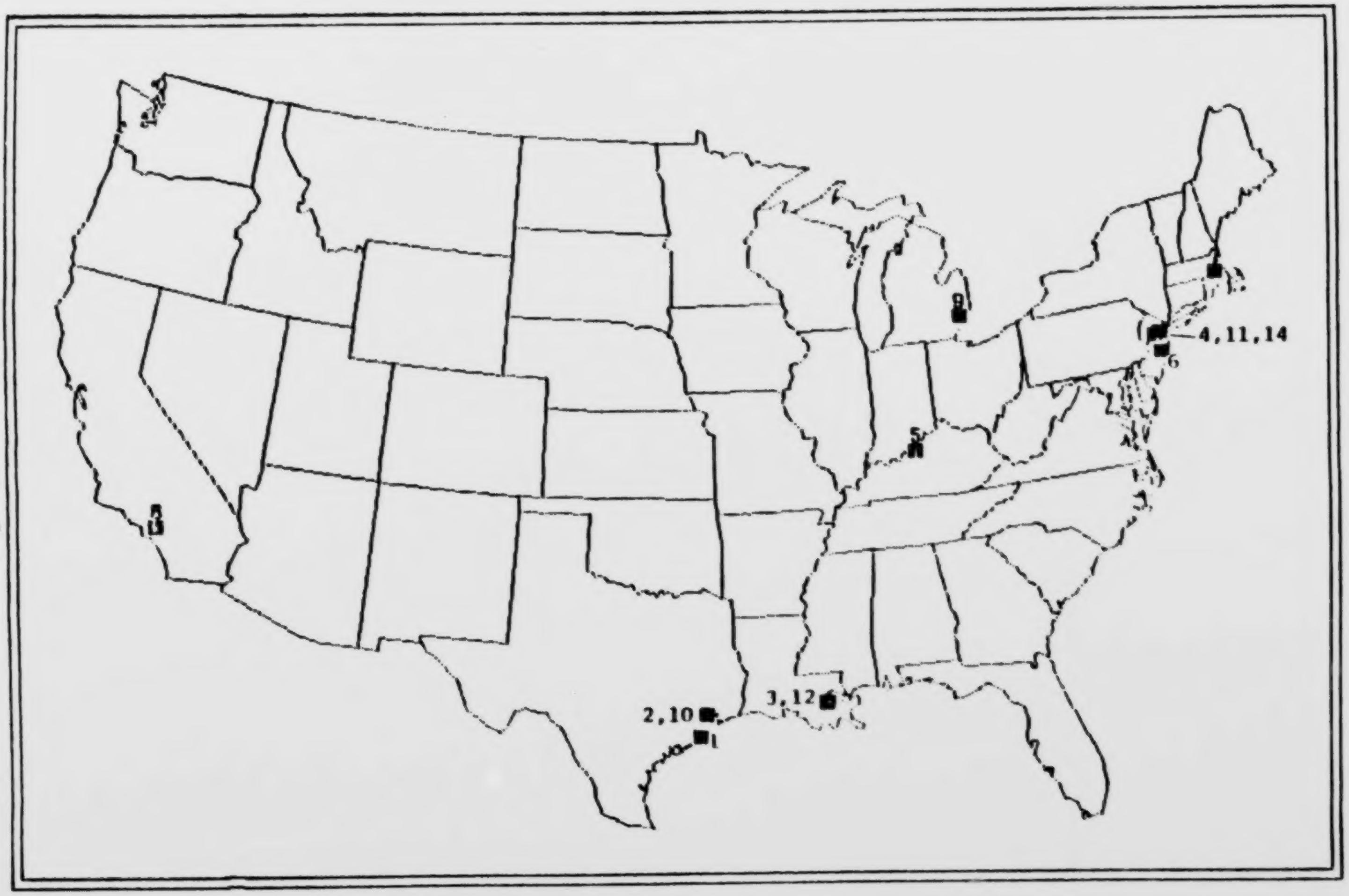

4,11,14
6
5
3,12
2,10
1

FIGURE 13-1 SPECIFIC POINT SOURCES OF EPICHLOROHYDRIN EMISSIONS

TABLE 13-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF EPICHLOROHYDRIN

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1 2	1.003968 1.001376	.023904 .087840	.095616 .245952
2	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	1	1 2	.441504 .590976	.010512 .065664	.042048 .114912
3	SHELL	NORCO, LA	30 00 11	090 23 42	12925	2	1	.441504	.010512	.042048
4	CELANESE	LINDEN, NJ	40 37 10	074 15 53	94741	3	2	.229824	.020160	.056448
5	CELANESE	LOUISVILLE, KY	38 11 00	085 50 00	93821	3	2	.147744	.012960	.036288
6	CIBA-GEIGY	TOMS RIVER, NJ	39 59 20	074 22 33	14706	3	2	.361152	.031680	.088704
7	REICHHOLD	ANDOVER, MA	42 08 30	071 08 28	14739	3	2	.049248	.004320	.012096
8	REICHHOLD	AZUSA, CA	34 07 52	117 53 51	23174	3	2	.049248	.004320	.012096
9	REICHHOLD	DETROIT, MI	42 28 17	083 07 52	14822	3	2	.049248	.004320	.012096
10	REICHHOLD	HOUSTON, TX	29 45 10	095 10 15	12906	3	2	.049240	.004320	.012096
11	UNION CARBIDE	BOUND BROOK, NJ	40 33 32	074 31 18	94741	3	2	.065664	.005760	.016128
12	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	3	2	.114912	.010080	.028224

* Plant Types:

Type 1: Plant produces epichlrohydrin, glycerins and epoxy resions

Type 2: Plant produces epichlorohydrin and glycerins

Type 3: Plant produces epoxy resins

† Source Types:

Type 1: Epichlorohydrin and glycerin production

Type 2: Epoxy resins production

TABLE 13-9. EXPOSURE AND DOSAGE OF EPICHLOROHYDRIN RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
10	2	28
5	25	172
2.5	158	591
1	822	1,550
0.5	4,806	4,270
0.25	20,499	9,380
0.1	86,056	19,200
0.05	232,925	29,500
0.025	480,983	37,900
0.01	1,291,751	50,700
0.005	2,365,630	58,000
0.00012*	10,565,428	70,400

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 13-10. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF EPICHLOROHYDRIN

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	1.165 gm/sec
Nation mobile source emissions (E_M)	0

TABLE 13-11. EPICHLORHYDRIN EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.005000	505140	3140.9	0.	100.0	0.	100.0	0.	0.
.002500	505140	3140.9	0.	100.0	0.	100.0	0.	0.
.001000	19111174	36094.9	0.	100.0	0.	100.0	0.	0.
.00500	43072401	53239.5	0.	100.0	0.	99.3	.1	.6
.000250	106150721	76295.7	0.	100.0	0.	96.7	1.6	1.7
.000100	150983815	84448.2	0.	100.0	0.	93.4	2.6	4.1
0.	158679135	84921.4	0.	100.0	0.	92.9	2.6	4.5

TABLE 13-12. EXPOSURE AND DOSAGE SUMMARY OF EPICHLOROHYDRIN

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
10	2	0	0	2	28	0	0	28
5	25	0	0	25	172	0	0	172
2.5	158	0	0	158	591	0	0	591
1	822	0	0	822	1,550	0	0	1,550
0.5	4,806	0	0	4,806	4,270	0	0	4,270
0.25	20,499	0	0	20,499	9,380	0	0	9,380
0.1	86,056	0	0	86,056	19,200	0	0	19,200
0.05	232,925	0	0	232,925	29,500	0	0	29,500
0.025	480,983	0	0	480,983	37,900	0	0	37,900
0.01	1,291,751	0	0	1,291,751	50,700	0	0	50,700
0.005	2,365,630	0	505,140	2,870,770	58,000	0	3,141	61,141
0.0025	--	0	505,140	--	--	0	3,141	--
0.001	--	0	19,111,174	--	--	0	36,095	--
0.0005	--	0	43,072,401	--	--	0	53,240	--
0.00025	--	0	106,150,721	--	--	0	76,296	--
0.0001	--	0	150,983,815	--	--	0	84,448	--
0	10,565,428	0	158,679,135	--	70,400	0	84,921	155,321

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

58/4

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6. D. B. Dimick, Dow Chemical, Freeport, TX, Texas Air Control Board Emissions Inventory Questionnaire for 1975, Epichlorohydrin, Glycerin No. 1.

7. Dow Chemical Co., Freeport, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Allyl Chloride, Glycerin II.

8. Shell Chemical Co., Deer Park, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Glycerin and Associated Products.

9. Shell Chemical Co., Norco, LA, Louisiana Air Control Commission Emission Inventory Questionnaire (January 31, 1977).

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APPENDIX A-14 ----- Ethylene Oxide

ETHYLENE OXIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-21-8

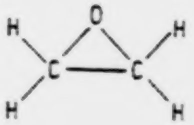
Synonyms: 1,2-Epoxyethane; Oxirane; Anprolene; Dihydrooxirene; Dimethylene oxide; Ethyleneoxide; ETO; Oxacyclopropane; Oxane; Oxidoethane; α,β-Oxidoethane

Chemical Formula

Molecular Weight: 44.05

Molecular Formula: C_2H_4O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Gas - colorless, flammable

Boiling Point: 13.5°C at 746 mm

Melting Point: -111.3°C

Density: 0.8711 at 20°C/20°C

Vapor Pressure: 1475 mm at 25°C

Vapor Density: 1.52

Solubility: Infinitely soluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): -0.3

Atmospheric Reactivity

Transformation Products:

Reactivity Toward $OH\cdot$: Same as butane

Reactivity Toward O_3: No reaction

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

I. PRODUCTION

A. PRODUCTION SITES

Ethylene oxide (CH_2OCH_2) can be produced by either the chlorohydrin process or the direct catalytic oxidation of ethylene using air or oxygen. Catalytic oxidation is now the preferred production method because of improved technology and the rising cost of chlorine. In the direct oxidation process, ethylene from a steam cracker is purified to remove catalyst poisons such as sulfur compounds. The oxidation of ethylene with air or oxygen is carried out in the presence of a silver catalyst. The present trend is to use oxygen in place of air to increase yields.[1,2]

There are 13 ethylene oxide producing locations in the United States. The locations of the plants and the 1978 capacity and estimated production level for each site are shown in Table 14-1. In 1978, an estimated 3640 million lb of ethylene oxide was produced.[1,2,3,4]

B. END-USE DISTRIBUTION

Table 14-2 shows the end-use distribution for ethylene oxide. Approximately 25% of the ethylene oxide produced is used to make ethylene glycol polyester and 23% is used to make ethylene glycol antifreeze. Ethylene glycol miscellaneous uses and surface active agents account for 10 and 15% of the use, respectively. Ethylene oxide is also used to produce diethylene glycol, triethylene glycol, glycol ethers, ethanolamines, and other miscellaneous products.

C. EMISSION ESTIMATES

Ethylene oxide emissions from production sites are presented in Tables 14-3 and 14-4. Emission estimates represent total ethylene oxide emissions for both production and usage at a particular site. Most of the production sites captively use the ethylene oxide produced for ethylene glycol and other uses. Table 3 shows the ethylene oxide emissions from producers using the air oxidation process. Total estimated emissions for 1978 were 1.28 million lb. Emission factors used to develop process vent, storage, and fugitive emission estimates are also shown in Table 14-3.[5] Process vent emissions originate primarily from the reactor vent and the stripper vent. Storage emissions represent the losses from both working and final product storage tanks as well as loading and unloading areas. The number of tanks at a facility is a function of production and tank sizes. Fugi-

Table 14-1. Ethylene Oxide Producers[a]

Source	Location	Type Process[b]	1978 Estimated Production[c] (10^6 lb/yr)	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates
BASF Wyandotte	Geismar, LA	B	222	310	30 11 34/91 00 42
Celanese	Clear Lake, TX	B	340	475	29 37 17/95 03 51
Dow	Freeport, TX	A	322	450	28 59 15/95 24 45
	Plaquemine, LA	A	351	490	30 19 00/91 15 32
Jefferson Chemical	Port Neches, TX	A	340	475	29 57 45/93 56 00
Northern Petrochemical	East Morris, IL	B	165	230	41 24 08/88 17 18
Olin	Brandenburg, KY	B	75	105	38 00 27/86 06 50
PPG	Beaumont, TX	B	107	150	30 03 40/94 02 30
Shell Chemical	Geismar, LA	B	193	270	30 11 00/90 59 00
Sunolin Chemical	Claymont, DE	B	72	100	39 48 20/75 25 40
Texas Eastman	Longview, TX	B	136	190	32 25 55/94 41 06
Union Carbide	Seadrift, TX	A	594	830	28 30 31/96 46 18
	Taft, LA	A	723	1010	29 58 00/97 27 00
Total			3640	5085	

[a] See refs 1—4.

[b] A = air oxidation process
B = oxygen oxidation process

[c] The distribution of production for each producer is determined by the ratio of total U.S. production/total capacity times individual site capacity.

Table 14-2. Ethylene Oxide End-Use Distribution 1978*

Use	Usage (10^6 lb/yr)	Usage (%)
Ethylene glycol polyester	910	25
Ethylene glycol antifreeze	837	23
Ethylene glycol (other uses)	364	10
Surface active agents	546	15
Ethanolamines	255	7
Glycol ethers	255	7
Other	473	13
Total	3640	100

*See refs 2 and 4.

Table 14-3. Ethylene Oxide Emissions from Producers[a]
(Air Oxidation Process)

Company	Location	Process Emission (lb)	Storage Emission (lb)	Fugitive Emission (lb)	Total Emissions[b] (lb)	Total Emissions[b] (g/sec)
Dow	Freeport, TX	169,000	6,880	529	176,000	2.5
	Plaquemine, LA	184,000	7,500	577	192,000	2.8
Jefferson	Port Neches, TX	179,000	7,270	559	186,000	2.7
Union Carbide	Seadrift, TX	312,000	12,700	977	326,000	4.7
	Taft, LA	380,000	15,500	1,190	396,000	5.7
Total		1,224,000	49,850	3,832	1,277,000	18.4

[a] Based on the following emission factors (lbs EO emitted per lb produced):

Process	0.000525	A - (derived from site visit data)
Storage	0.000021	A - (derived from site visit data)
Fugitive	0.000002	A - (derived from site visit data)
	0.000548	

[b] See ref. 5.

Table 14-4. Ethylene Oxide Emissions from Producers[a]
(Oxygen Oxidation Process)

Company	Location	Process Emission (lb)	Storage Emission (lb)	Fugitive Emission (lb)	Total Emissions[b] (lb)	Total Emissions[b] (g/sec)
BASF	Geismar, LA	1,032	156	12	1,200	0.02
Celanese	Clear Lake, TX	135	12	1,853	2,000	0.03
Northern Petrochemical	East Morris, IL	77,340	11,690	899	89,930	1.3
Olin	Brandenburg, KY	35,150	5,314	409	40,880	0.6
PPG	Beaumont, TX	50,150	7,581	583	58,320	0.8
Shell Chemical	Geismar, LA	90,460	13,670	1,052	105,200	1.5
Sunolin Chemical	Claymont, DE	33,750	5,101	392	39,240	0.6
Texas Eastman	Longview, TX	63,740	9,636	741	74,120	1.1
Total		351,667	53,158	5,942	410,900	5.9

[a] Based on the following emission factors (lb EO emitted per lb produced):

Process	0.000470	A - (derived from site visit data)
Storage	0.000071	A - (derived from site visit data)
Fugitive	0.000005	A - (derived from site visit data)
	0.000546	

[b] See ref. 5.

[c] See ref. 6.

[d] See ref. 7.

tive emissions are those that result from plant equipment. Emission estimates are based on a plant operating schedule of 24 hr/day, 7 days/week, 52 weeks/yr. Table 14-4 shows the ethylene oxide emissions from producers using the oxygen oxidation process.

Total estimated emissions for 1978 were 0.41 million lb. Emission factors used to develop emission estimates also are shown in Table 14-4.

Ethylene oxide production and end-use vent stack data by each of the two processes used to manufacture are shown in Table 14-5.

II. USER SITES

A. USER SITES

The user sites for ethylene oxide are the same as the production sites shown previously in Table 14-1. Table 14-6 shows the ethylene oxide producing locations, the use or uses of ethylene oxide at each site, and the 1978 capacities for each of the products at each site.

B. EMISSION ESTIMATES

Ethylene oxide emissions from users of ethylene oxide are included in total emissions shown previously in Tables 14-3 and 14-4. Although the end-uses of ethylene oxide vary at different plants (as shown in Table 14-6), only one set of emission factors for the two basic production processes was used to estimate emissions from captive ethylene oxide production and use at the various manufacturing sites. There are two sites, Oxirane in Channelview, TX, and ICI in Hopewell, VA, which produce ethylene glycol directly without actually producing ethylene oxide. Oxirane utilizes a new process called acetozylation to produce ethylene glycol.

There should be no ethylene oxide emissions from these two sites since ethylene oxide is not one of the products or intermediates in the acetozylation process. Mono and diacetates are formed in this process when ethylene is reacted with acetic acid in the presence of catalysts such as tellurium and bromine.

Table 14-5. Ethylene Oxide Vent Parameters[a]

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Air oxidation process[b]					
Process	2	55	2.00	110	345
Storage	8	32	0.17	50	
Fugitive[c]					
Oxygen oxidation process[b]					
Process	3	66	1.00	140	100
Storage	8	32	0.17	50	
Fugitive[d]					

[a] See ref. 5.

[b] Building cross-section - 200 m^2.

[c] Fugitive emissions are distributed over a rectangular area 350 ft X 1350 ft.

[d] Fugitive emissions are distributed over a rectangular area 350 ft X 1000 ft.

Table 14-6. Ethylene Oxide Producers and Users

Company	Location	1978 Capacity (lb X 10^6)					
		Ethylene Oxide	Ethylene Glycol	Diethylene Glycol	Triethylene Glycol	Glycol Ethers	Ethanol-amines
BASF	Geismar, LA	310		20		230	
Celanese	Clear Lake, TX	475		50	10		
Dow	Freeport, TX	450	330	25	50		40
	Plaquemine, LA	490	550	50			100
Jefferson	Port Neches, TX	475	360	35	20	40	80
Northern Petrochemical	East Morris, IL	230	350	35			
Olin	Brandenburg, KY	105	50	5	2	70	25
PPG	Beaumont, TX	150	200	20		20	
Shell	Geismar, LA	270	200	20	5	50	
Sunolin	Claymont, DE	100					
Texas Eastman	Longview, TX	190	180	20		25	
Union Carbide	Seadrift, TX	830	870	80	75*	490*	230
	Taft, LA	1010	1200	100			
ICI	Hopewell, VA		33				

***Includes a plant in Penuelas, Puerto Rico.**

Oxirane's Channelview, TX facility has shut down (ref. 8)

III. TOTAL EMISSIONS

Table 14-7 summarizes the total ethylene oxide emissions from producers and users. Since ethylene oxide emissions were reported for both combined production and usage, the total emissions from producers also include the various user categories for ethylene oxide. Total nationwide emissions of ethylene oxide were estimated to have been 1,687,900 lb in 1978.

Table 14-7. Estimated 1978 Ethylene Oxide Nationwide Emissions

Source	Production/ Usage (10^6 lb/yr)	Usage (%)	Total Emissions (lb/yr)	Total Emissions (g/sec)
Producers[a]				
Air oxidation	2330		1,277,000	18.4
Oxygen oxidation	1310		410,900	5.9
Users				
EG[b] polyester	910	25		
EG antifreeze	837	23		
EG (other uses)	364	10		
Surface active agents	546	15		
Ethanolamines	255	7		
Glycol ethers	255	7		
Other	473	13		
Total			1,687,900	24.3

[a] Total emissions from producers also include total emissions from users, since ethylene oxide is produced and used at the same site.

[b] EG = ethylene glycol.

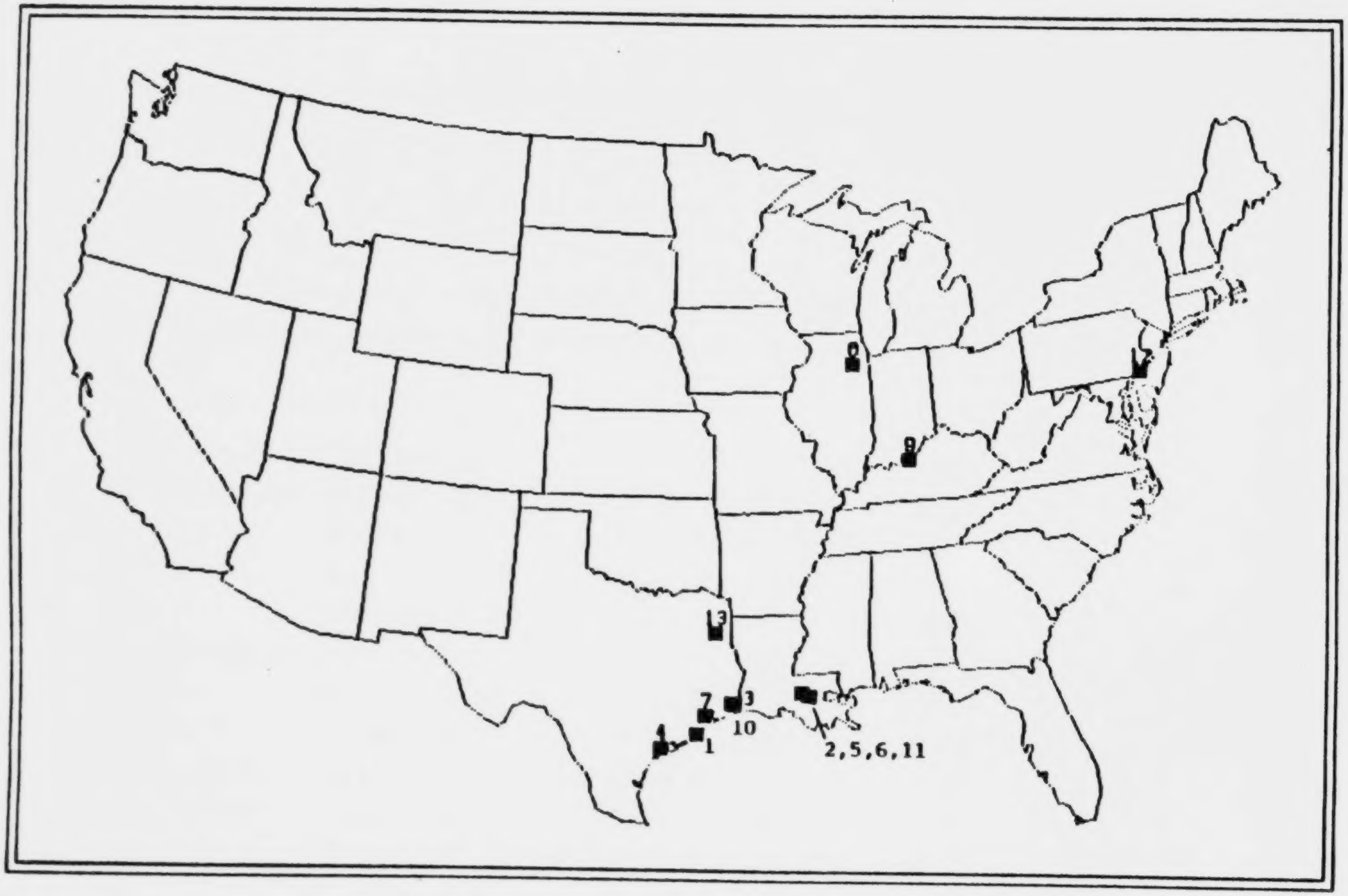

9
8
12
13
7
3
10
4
1
2,5,6,11

FIGURE 14-1. SPECIFIC POINT SOURCES OF ETHYLENE OXIDE EMISSIONS

Table 14-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF ETHYLENE OXIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	2.433600	.099061	.007610
2	DOW	PLAQUEMINE, LA	30 19 00	091 15 00	23202	1	1	2.649607	.108004	.008308
3	JEFFERSON	PORT NECHES, TX	29 57 45	093 56 00	12917	1	1	2.577625	.104674	.008054
4	UNION CARBIDE	SEARIFT, TX	28 30 31	096 46 10	12923	1	1	4.492643	.182870	.014079
5	UNION CARBIDE	TAFT, LA	27 58 00	097 27 00	13958	1	1	5.471841	.223205	.017123
6	BASF	GEISMAR, LA	30 11 34	091 00 42	13970	2	2	.022260	.002251	.000159
7	CELANESE	CLEAR LAKE, TX	29 37 17	095 03 51	12906	2	2	.001934	.000159	.026668
8	N PETROCHEMICAL	EAST MORRIS, IL	41 24 08	088 17 18	94846	2	2	1.11241	.168347	.012938
9	OLIN	BRANDENBURG, KY	38 00 27	086 06 50	13807	2	2	.506152	.076516	.005898
10	PPG	BEAUMONT, TX	30 03 40	094 02 30	12917	2	2	.722159	.109177	.008403
11	SHELL	GEISMAR, LA	30 11 00	090 59 00	12958	2	2	1.302606	.196854	.015157
12	SUNOLIN CHEMICAL	CLAYMONT, DE	39 48 20	075 25 40	94741	2	2	.485984	.073440	.005644
13	TEXAS EASTMAN	LONGVIEW, TX	32 25 55	094 41 06	13972	2	2	.917840	.138762	.010654

---

* Plant Types:

Type 1: Plant produces ethylene oxide by using the air oxidation process

Type 2: Plant produces ethylene oxide by using the oxygen oxidation process

+ Source Types:

Type 1: Ethylene oxide production (Air oxidation process)

Type 2: Ethylene oxide production (Oxygen oxidation process)

TABLE 14-9. EXPOSURE AND DOSAGE OF ETHYLENE OXIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
5	37	238
2.5	133	577
1	3,744	5,920
0.5	12,131	11,700
0.25	20,968	14,700
0.1	127,410	30,500
0.05	329,480	44,300
0.025	627,370	55,000
0.01	1,026,800	61,600
0.005	1,361,211	63,900
5.76x10^{-5}*	2,144,290	65,800

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

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APPENDIX A-15 ----- Formaldehyde

FORMALDEHYDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 50-00-0

Synonyms: Methanal; Methyl Aldehyde; Formalin; Oxomethane; Oxymethylene; Methylene Oxide; Formic Aldehyde

Chemical Formula

Molecular Weight: 30.03

Molecular Formula: CH_2O

Molecular Structure:

$$\overset{\overset{\displaystyle O}{\|}}{\mathrm{H - C - H}}$$

Chemical and Physical Properties

Physical State at STP: Gas - Flammable, colorless

Boiling Point: -21°C at 760 mm

Melting Point: -92°C

Density: 0.815 at 20°C/4°C

Vapor Pressure: 1946.67 mm at 25°C

Vapor Density: 1.075

Solubility: Soluble (370 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): -0.96

Atmospheric Reactivity

Transformation Products: Carbon monoxide; water

Reactivity Toward OH·: 2-4 x butane

Reactivity Toward O_3:

Reactivity Toward Photolysis: 9% per hour at full sunlight

Major Atmospheric Precursors: Hydrocarbons (photooxidation)

Formation Reactivity: Equilibrium ~ 5% NMHC. Formed by incomplete combustion of many organic substances. Present in coal and

I. SOURCES

Formaldehyde is currently produced in the United States by two different processes, both of which use methanol as a raw material.[1,2] The predominant process, by which 75% of the formaldehyde is manufactured, involves the use of a metallic silver catalyst (silver process). Formaldehyde is formed from methanol by a combination of oxidation and dehydrogenation reactions.[1,2]

The alternate process, by which 25% of the formaldehyde is produced, involves the use of a metal oxide catalyst (metal oxide process). In this process, formaldehyde is formed exclusively by oxidation.

Formaldehyde is produced by 16 companies at 53 locations in the United States.[1,2] Because most of the formaldehyde is manufactured and shipped as a solution containing 50% or more water, the distance from the producing point to the consuming point must be minimized to reduce shipping costs; therefore, the industry is characterized by a large number of relatively small plants. Since more than half the formaldehyde used is in the manufacture of adhesives for wood products, the producing plants are located predominantly in the south and west. The plant locations and the 1978 capacity and estimated production level for each plant are shown in Table 15-1. An estimated 6400 million lb of 37% formaldehyde solution was produced in 1978.[1,2,3]

Formaldehyde has many diverse end-uses. The largest end-use is in the production of urea-formaldehyde, phenol-formaldehyde, and melamine-formaldehyde resins which are, in turn, primarily consumed by the wood products industry. This end-use consumed an estimated 54% of production in 1978 amounting to 3,460 million lb. Of this total, 1,630 million lb was used to produce urea-formaldehyde resins, 1,560 million lb to produce phenol-formaldehyde resins, and 270 million lb to produce melamine-formaldehyde resins.[1,2,4] The balance of the formaldehyde produced is consumed as a chemical intermediate in a variety of products.

Other applications of formaldehyde include its use in the production of elastomers, explosives, plastics, fibers, fertilizer, chelating agents, alkyd resins (protective coatings), textiles, and dyes.[1] Total consumption for this broad category is estimated to have been 2,940 million lb in 1978. Because of the undesirability

Table 15-1. Production of Formaldehyde[a]

Source	Location	1978 Estimated Production (M lb)[b]	1978 Estimated Capacity (M lb)	Geographic Coordinates
Allied Chemical	South Point, OH	222	310	38 25 43/82 36 00
Borden, Inc.	Demopolis, AL	72	100	32 30 48/27 50 06
	Diboll, TX	57	80	31 11 52/94 46 50
	Fayetteville, NC	168	235	35 01 43/78 51 41
	Geismar, LA	179	250	30 13 00/91 01 00
	Louisville, KY	57	80	38 12 09/85 51 49
	Sheboygan, WI	93	130	43 45 26/87 46 17
	Fremont, CA	161	225	37 32 06/121 57 24
	Kent, WA	57	80	47 23 12/122 13 15
	LaGrande, OK	46	65	45 20 33/100 02 02
	Missoula, MT	64	90	46 54 10/114 40 00
	Springfield, OR	172	240	44 02 60/122 59 06
Celanese Chemical	Bishop, TX	1075	1500	27 34 06/97 49 27
	Newark, NJ	84	117	40 43 30/74 07 25
	Rock Hill, SC	84	117	34 57 25/80 57 32
Chembond Corp.	Springfield, OR	107	150	44 02 60/122 59 06
	Winnifield, LA	50	70	31 54 49/92 40 35
Du Pont	Belle, WV	358	500	38 12 13/81 28 34
	LaPorte, TX	229	320	29 42 04/95 02 05
	Healing Springs, NC	158	220	35 01 56/80 10 30
	Linden, NJ	115	160	40 36 02/74 12 08
	Toledo, OH	193	270	41 39 22/83 33 20
GAF Corp.	Calvert City, KY	72	100	37 02 50/88 21 12

Table 15-1 (Continued)

Source	Location	1978 Estimated Production (M lb)^{b}	1978 Estimated Capacity (M lb)	Geographic Coordinates
Georgia-Pacific Corp.	Albany, OR	86	120	44 37 07/123 05 13
	Columbus, OH	72	100	39 53 07/82 56 45
	Coosbay, OR	65	90	42 27 26/124 10 47
	Crossett, AR	115	160	33 08 36/93 02 11
	Russelville, SC	143	200	33 20 52/79 58 00
	Taylorsville, MS	86	120	39 51 00/89 25 00
	Vienna, GA	72	100	37 07 30/83 49 00
	Lufkin, TX	72	100	31 21 00/94 47 00
Gulf Oil Corp.	Vicksburg, MS	43	60	32 17 00/90 54 00
Hercules Inc.	Louisiana, MO	122	170	39 26 24/91 03 37
	Wilmington, NC	72	100	34 19 09/77 59 23
Hooker Chemicals & Plastics	Tonawanda, NY	97	135	43 02 47/78 51 44
IMC Chemical Group	Seiple, PA	47	65	40 38 12/75 31 58
	Sterlington, LA	22	30	32 43 25/92 08 56
Monsanto Corp.	Addyston, OH	72	100	39 07 30/84 42 58
	Chocolate Bayou, TX	140	195	29 14 55/95 12 45
	Eugene, OR	72	100	44 02 59/123 08 19
	Springfield, MA	211	295	42 09 33/72 29 09
Pacific Resins and Chemicals	Eugene, OR	68	95	44 01 00/123 05 05

Table 15-1 (concluded)

Source	Location	1978 Estimated Production (M lb)[b]	1978 Estimated Capacity (M lb)	Geographic Coordinates
Reichhold Chemicals, Inc.	Hampton, SC	36	50	32 53 33/81 06 10
	Houston, TX	86	120	29 44 50/95 10 00
	Kansas City, KA	36	50	39 09 28/94 37 41
	Malvern, AR	79	110	34 24 09/92 48 45
Reichhold Chemicals, Inc.	Moncure, NC	86	120	35 31 18/79 04 52
	Tacoma, WA	36	50	47 16 11/122 22 57
	Tuscaloosa, AL	50	70	33 12 03/87 34 00
	White City, OR	179	250	42 26 18/122 07 07
Tenneco, Inc.	Fords, NJ	133	185	40 30 50/74 19 17
	Garfield, NJ	72	100	40 52 28/74 06 49
Wright Chemical Corp.	Riegelwood, NC	57	80	34 19 22/78 12 09
Total		6400	8929	

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[a] See refs. 1—3.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

of transporting formaldehyde exports accounted for only 30 million lb (0.5%) of domestic production in 1978.[2] Formaldehyde end-uses are summarized in Table 15-2.

II. EMISSION ESTIMATES

A. PRODUCTION

Estimated production losses are shown in Table 15-3 for each of the 53 producing locations. Total emissions of formaldehyde from production facilities are estimated to be 1,939,700 lb. Process emissions from both types of processes originate primarily from the product absorber vent. Other emission components include methanol, methyl formate, methylal from the metallic-silver-catalyst process, and methanol and dimethyl ether from the metal-oxide-catlayst process. Storage emissions, which account for about 8.0% of estimated production losses, represent the total losses from both working and final product storage tanks and from loading and handling. Fugitive emissions (15.7% of total formaldehyde emissions) are those which result from plant equipment leaks.

Vent stack data are shown in Table 15-4. Normally two process and six storage tank vents are involved in the production and storage emissions from the metallic-silver-catalyst process, and one process vent and six storage tank vents are involved in emissions from the metal-oxide-catalyst process. Usually formaldehyde production facilities are "open-air" structures without walls or solid floors (i.e., steel grating). Only the control room area is enclosed.

B. USES

Emissions resulting from the production of urea-formaldehyde, phenol-formaldehyde, and melamine-formaldehyde resins were estimated to have been 8.15, 7.8 and 1.35 million lb respectively in 1978. The average emission rates per site, the total number of sites, and the total emissions per region are shown in Table 15-5. Table 15-6 lists the producers of each type of resin and the plant locations. Emissions were estimated from the resin emission factor shown in Table 15-7.[5,6]

Table 15-8[1] lists the site locations and Table 15-9 the emission estimates for the other major chemical intermediate uses of formaldehyde. They are based on the emission factors shown in Table 15-7.

Table 15-2. Formaldehyde Consumption by End Use[a]

End-Use	Percent of Total Consumption	End-Use Consumption[b] ($\bar{M}$ lb)
Urea resins	25.4	1630
Phenolic resins	24.3	1560
Butanediol	7.7	490
Acetal resins	7.0	450
Pentaerythritol	6.0	380
Hexamethylenetetramine	4.5	290
Melamine resins	4.2	270
Urea formaldehyde concentrates	3.6	230
Chelating agents	3.6	230
Trimethylolpropane	1.3	80
Other chemical intermediate uses	11.9	760
Export	0.5	30
Total	100	6400

[a] See refs 1—4.

[b] As 37% solution.

Table 15-3. FORMALDEHYDE PRODUCTION EMISSIONS[a]

Company	Location	Production (lb x 10^6)	Type[b] Process	Process Emissions (lb x 10^4)	Storage Emissions (lb x 10^4)	Fugitive Emissions (lb x 10^4)	Total Emissions (lb x 10^4)[c]	Total Emissions (g/sec)[d]
Allied Chemical	South Point, OH	222	A	5.81	0.46	0.91	7.19	1.04
Borden	Demopolis, AL	72	A	1.89	0.15	0.30	2.33	0.34
	Diboll, TX	57	A	1.49	0.12	0.23	1.85	0.27
	Fayetteville, NC	168	A	4.40	0.35	0.69	5.44	0.78
	Geismar, LA	179	A	4.69	0.37	0.74	5.79	0.83
	Louisville, KY	57	A	1.49	0.12	0.23	1.85	0.27
	Sheboygan, WI	93	A	2.44	0.19	0.38	3.01	0.43
	Freemont, CA	161	A	4.22	0.33	0.66	5.21	0.75
	Kent, WA	57	A	1.49	0.12	0.23	1.85	0.27
	LaGrande, OR	46	A	1.21	0.09	0.19	1.49	0.21
	Missoula, MT	64	A	1.68	0.13	0.26	2.07	0.30
	Springfield, OR	172	A	4.51	0.35	0.71	5.57	0.80
Celanese Chemical[e]	Bishop, TX	1,075	A	8.84	0.70	1.36	10.98	1.58
	Newark, NJ	84	B	3.30	0.43	0.68	4.41	0.63
	Rock Hill, SC	84	B	3.30	0.43	0.68	4.41	0.63
Chembond	Springfield, OR	107	B	4.20	0.55	0.86	5.62	0.81
	Winnifield, LA	50	B	1.96	0.26	0.40	2.62	0.38
DuPont	Belle, WV	358	A	9.38	0.74	1.47	11.59	1.67
	LaPorte, TX	229	A	6.00	0.47	0.94	7.41	1.07
	Healing Springs, NC	158	A	4.14	0.33	0.65	5.11	0.74
	Linden, NJ	115	A	3.01	0.24	0.47	3.72	0.54
	Toledo, OH	193	A	5.06	0.40	0.79	6.25	0.90

Table 15-3. FORMALDEHYDE PRODUCTION EMISSIONS[a] (continued)

Company	Location	Production (lb x 10^6)	Type[b] Process	Process Emissions (lb x 10^4)	Storage Emissions (lb x 10^4)	Fugitive Emissions (lb x 10^4)	Total Emissions (lb x 10^4)[c]	Total Emissions (g/sec)[d]
GAF	Calvert City, KY	72	B	2.83	0.37	0.58	3.78	0.54
Georgia-Pacific[f]	Albany, OR	86	B	3.38	0.44	0.69	4.51	0.65
	Columbus, OH	72	B	2.83	0.37	0.58	3.78	0.54
	Coos Bay, OR	65	B	2.55	0.34	0.52	3.41	0.49
	Crossett, AR	72	A	0.00	0.15	0.30	0.45	0.06
		43	B	0.00	0.22	0.35	0.57	0.08
	Russelville, SC	143	B	5.61	0.74	1.15	7.51	1.08
	Taylorsville, MS	86	B	3.38	0.44	0.69	4.51	0.65
	Vienna, GA	72	A	0.00	0.15	0.30	0.45	0.06
	Lufkin, TX	72	B	0.00	0.37	0.58	0.95	0.14
Gulf Oil	Vicksburg, MS	43	B	1.69	0.22	0.35	2.26	0.33
Hercules	Louisiana, MO	122	A	3.20	0.25	0.50	3.95	0.57
	Wilmington, NC	72	A	1.89	0.15	0.30	2.33	0.34
Hooker Chamicals & Plastics	Tonawanda, NY	97	A	2.54	0.20	0.40	3.14	0.45
IMC Chemical Group	Seiple, PA	47	A	1.23	0.10	0.19	1.52	0.22
	Sterlington, LA	22	A	0.58	0.05	0.09	0.71	0.10
Monsanto	Addyston, OH	72	A	0.34	0.03	0.05	0.42	0.06
	Cholocate Bayou, TX	140	A	0.66	0.05	0.11	0.82	0.12
	Eugene, OR	72	A	0.34	0.03	0.05	0.42	0.06
	Springfield, MA	211	A	1.00	0.08	0.16	1.23	0.18

Table 15-3. FORMALDEHYDE PRODUCTION EMISSIONS[a] (concluded)

Company	Location	Production (lb x 10^6)	Type[b] Process	Process Emissions (lb x 10^4)	Storage Emissions (lb x 10^4)	Fugitive Emissions (lb x 10^4)	Total Emissions (lb x 10^4)[c]	Total Emissions (g/sec)[d]
Pacific Resins & Chemicals	Eugene, OR	68	A	1.78	0.14	0.28	2.20	0.32
Reichhold Chemicals	Hampton, SC	36	A	0.94	0.07	0.15	1.17	0.17
	Houston, TX	86	B	3.38	0.44	0.69	4.51	0.65
	Kansas City, KA	36	A	0.94	0.07	0.15	1.17	0.17
	Melvern, AR	79	B	3.10	0.41	0.64	4.15	0.60
	Moncure, NC	86	B	3.38	0.44	0.69	4.51	0.65
	Tacoma, WA	36	B	1.41	0.19	0.29	1.89	0.27
	Tuscaloosa, AL	50	A	1.31	0.10	0.21	1.62	0.23
	White City, OR	179	B	7.03	0.93	1.44	9.40	1.35
Tenneco	Fords, NJ	71	A	1.86	0.15	0.29	2.30	
		62	B	2.43	0.32	0.50	3.25	
	Garfield, NJ	72	A	1.89	0.15	0.30	2.33	
Wright Chemical	Riegelwood, NC	57	B	2.24	0.29	0.46	2.99	
Total		6,400		150.24	15.76	30.86	193.97	

[a] See ref. 2.

[b] A - silver process
B - metal oxide process

[c] Emission factors for formaldehyde production (lb formaldehyde lost/lb formaldehyde produced):

	Silver Process	Metal Oxide Process
Process	0.0002620 A	0.0003930 A - Derived from site visit data
Storage	0.0000206 A	0.0000517 A - Derived from site visit data
Fugitive	0.0000411 A	0.0000806 A - Derived from site visit data
	0.0003237	0.0005253

[d] 8760 operating hours per year; i.e., 24/day, 7 day/wk, 52 wk/yr.

[e] See ref. 7.

[f] See ref. 8.

[g] See ref. 10.

Table 15-4. Formaldehyde Vent Parameters[a]

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Production						
Process	1	100	2	500	30	
Storage	6	24	0.66	80		
Fugitive						160 X 500
Resins[b]						
Process	1	60	0.33	150	20	
Storage	2	24	0.17	80		
Fugitive						100 X 100
Butanediol						
Process	1	40	0.50	190	40	
Storage	2	24	0.33	80		
Fugitive						100 X 200
Pentaerythritol						
Process	3	140	1.5	140	175	
Storage	2	20	0.33	70		
Fugitive						100 X 200

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Table 15-4 (concluded)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Hexamethylene tetramine						
Process	1	60	0.33	160	45	
Storage	2	24	0.17	80		
Fugitive						200 X 200
Trimethylolpropane						
Process	2	15	0.13	150	68	
Storage	1	20	0.17	80		
Fugitive						100 X 200

[a] Building cross-section for production and uses - 50 m^2.

[b] Includes urea, phenolic, melamine and acetal resins.

Table 15-5. Formaldehyde Emissions from Resin Producers by Region

Region	Phenolic Resins		Urea Resins		Melamine Resins	
	Number of Sites	Formaldehyde Emissions[a] (lb/yr)	Number of Sites	Formaldehyde Emissions[b] (lb/yr)	Number of Sites	Formaldehyde Emissions[c] (lb/yr)
New England	6	374,400	12	674,460	11	148,500
Middle Atlantic	26	1,622,400	21	1,180,305	15	202,500
East North Central	31	1,934,400	24	1,348,920	15	202,500
West North Central	5	312,000	4	224,820	3	40,500
South Atlantic	15	936,000	27	1,517,535	20	270,000
East South Central	6	374,400	17	955,485	12	162,000
West South Central	11	686,400	15	843,075	8	108,000
Mountain	1	62,400	1	56,205	0	0
Pacific	24	1,497,600	24	1,348,920	16	216,000
Total	125	7,800,000	145	8,150,000[b]	100	1,350,000[c]

[a] Average emissions per site: 62,400 lb/yr (0.90 g/sec).

[b] Average emissions per site: 56,205 lb/yr (0.81 g/sec).

[c] Average emissions per site: 13,500 lb/yr (0.19 g/sec).

Table 15-6. Producers of Formaldehyde-Based Resins[a]

Producer	Location	Type of Resin Produced		
		Phenolic	Urea	Melamine
Allied Chemical	South Point, OH		X	
	Toledo, OH	X	X	X
American Cyanamid	Columbia, SC			X
	Evendale, OH	X		X
	Azusa, CA		X	X
	Longview, WA		X	X
	Wollingford, CN		X	X
Ashland Oil	Clevelend, OH	X		
	Hammond, IN	X		
	Calumet City, IL	X		
	Fords, NJ	X		
	Pensacola, FL	X		
Auralux Chemical	Hope Valley, RI		X	X
Bendix	Green Island, NY	X		
Borden	Bainbridge, NY	X	X	X
	Demopolis, AL	X	X	X
	Diboll, TX		X	X
	Fayetteville, NC	X	X	X
	Louisville, KY		X	X
	Sheboygan, WI	X	X	X
	Freemont, CA	X	X	
	Kent, WA	X	X	X
	LaGrande, OR	X	X	
	Missoula, MT	X	X	
	Springfield, OR	X	X	X
Brand-S	Eugene, OR	X		
Carborundum	Wheatfield, NY	X		
Cargill	Carpentersville, IL		X	X
	Philadelphia, PA		X	X
Celanese	Charlotte, NC		X	
	Louisville, KY		X	X
Champion International	Redding CA	X	X	X

Table 15-6 (Continued)

Producer	Location	Type of Resin Produced Phenolic	 Urea	 Melamine
Clark Chemical	Blue Island, IL	X		
CNC Chemical	Providence, RI		X	X
Combustion Engineering	Muse, PA	X		
Commercial Products	Hawthorne, NJ		X	
Conchemco	Baltimore MD		X	X
	Kansas City, MO		X	X
Consolidated Papers	Wisconsin Rapids, WI		X	
Conwed	Cloquet, MN		X	
Cook Paint & Varnish	Detroit, MI		X	X
	North Kansas, MO		X	X
Core-Lube	Danville, IL	X		
CPC International	Forest Park, IL	X		
Dan River	Danville, VA		X	X
De Soto	Berkeley, CA		X	
	Garland, TX		X	
The Dexter Corp.	Waukegan, IL	X		
Dock Resins	Linden, NJ		X	X
The Duplan Corp	Brodhead, WI			X
Eastern Color & Chemical	Providence, RI		X	X
Emkay Chemical	Elizabeth, NJ		X	X
Exxon	Odenton, MD	X		X
The Fiberite Corp.	Winona, MN			X
Ford Motor	Mt. Clemens, MI			X
GAF	Chattanooga, TN		X	
General Electric	Coshocton, OH	X		
	Schenectady, NY	X		
	Pittsfield, MA	X		
The P.D. George Co.	St. Louis, MO	X		

Table 15-6 (Continued)

		Type of Resin Produced		
Producer	Location	Phenolic	Urea	Melamine
Georgia-Pacific	Albany, OR	X	X	X
	Columbus, OH	X	X	X
	Conway, NC	X	X	X
	Coos Bay, OR	X	X	X
	Crossett, AR	X	X	X
	Louisville, MS	X	X	X
	Lufkin, TX	X	X	X
	Russellville, SC	X	X	X
	Savannah, GA	X	X	X
	Taylorsville, MS	X	X	X
	Tewkesbury, MA	X		
	Ukiah, CA		X	X
	Vienna, GA	X	X	X
Getty Oil	Andalusia, AL	X	X	
	Spokane, WA	X		
	Springfield, OR	X	X	
	Winnfield, LA	X		
Gilman Paint & Varnish	Chattanooga, TN	X		
W. R. Grace	Alliance, OH		X	
	Charleston, SC		X	
	Columbus, OH		X	
	Finley, OH		X	
	Fort Pierce, FL		X	
	Henrietta, IL		X	
	Lansing, MI		X	
	Memphis, TN		X	
	San Juan, PR		X	
	Statesville, NC		X	
	Tampa, FL		X	
	Tulsa, OK		X	
	Wilmington, NC		X	
Guardsman Chemicals	Grand Rapids, MI		X	X

Table 15-6 (Continued)

Producer	Location	Type of Resin Produced Phenolic	Urea	Melamine
Gulf Oil	Alexandria, LA	X	X	
	High Point, NC	X	X	X
	Lansdale, PA	X	X	X
	Shawano, WI		X	X
	Valleyfield, Quebec		X	
	West Memphis, AR		X	
Hanna Chemical Coatings	Birmingham, AL		X	X
Hart Products	Jersey City, NJ		X	X
Hercules	Chicopee, MA		X	
	Hattiesburg, MS		X	
	Milwaukee, WI		X	
	Marshalton, DE	X		
Hersite and Chemical	Manitowoc, WI	X		
H & N Chemical	Totowa, NJ		X	
E. F. Houghton	Philadelphia, PA		X	
Inland Steel	Alsip, IL	X		
Inmont	Anaheim, CA	X		
	Cincinnati, OH	X		
	Detroit, MI	X		
	Greenville, OH	X		
International Minerals & Chemicals	Detroit, MI	X		
The Ironsides Co.	Columbus, OH	X		
Knoedler Chemical	Lancaster, PA	X		
Koppers	Bridgeville, PA	X	X	X
Kordell Industries	Mishawaka, IN	X		
Lawter Chemicals	S. Kearney, NJ	X		
Magna	Houston, TX	X		
The Marblette Corporation	Long Island City, NY	X		
Masonite	Gulfport, MS	X		
Millmaster Onyx	Lyndhurst, NJ		X	

Table 15-6 (Continued)

Producer	Location	Type of Resin Produced		
		Phenolic	Urea	Melamine
Minnesota Mining and Manufacturing	Cordova, IL	X		
	Cottage Grove, MN	X		
Mobil Oil	Kankakee, IL		X	X
Monsanto	Addyston, OH	X		
	Alvin, TX	X	X	
	Eugene, OR	X	X	X
	La Salle, Quebec		X	X
	Santa Clara, CA	X	X	X
	Springfield, MA	X	X	X
Napko	Houston, TX	X		
National Casein	Chicago, IL		X	
	Tyler, TX		X	
National Casein of California	Santa Ana, CA		X	
National Casein of New Jersey	Riverton, NJ		X	
National Starch and Chemical	Salisbury, NC		X	X
Occidental Petroleum	Kenton, OH	X		
	N. Tonawanda, NY	X		
Onyx Oils & Resins	Newark, NJ	X	X	X
Owens-Corning Fiberglas	Barrington, NJ	X		
	Kansas City, KA	X		
	Newark, OH	X		
	Waxahachie, TX	X		
Pat Chemical	Greenville, SC			X
Patent Plastics	Knoxville, TN		X	X
Perstorp U.S.	Florence, MA		X[b]	X
Pioneer Plastics	Auburn, ME	X	X	
Plastics Engineering	Sheboygan, WI	X		X
Plastics Manufacturing	Dallas, TX		X	X
Polymer Applications	Tonawanda, NY	X		
Polyrez	Woodbury, NJ	X		

Table 15-6 (Continued)

Producer	Location	Type of Resin Produced		
		Phenolic	Urea	Melamine
PPG Industries	Circleville, OH		X	X
	Oak Creek, WI		X	X
Raybestos-Manhattan	Stratford, CT	X		
Reichhold Chemicals	Andover, MA	X	X	X
	Azusa, CA		X	
	Carteret, NJ	X		
	Detroit, MI	X	X	X
	Houston, TX	X	X	
	Kansas City, KS	X		
	Malvern, AR		X	X
	Moncure, NC	X	X	
	Niagara Falls, NY	X		
	S. San Francisco, CA	X	X	X
	Tacoma, WA	X	X	X
	Tuscaloosa, AL	X	X	X
	White City, OR	X	X	X
Riegel Textile	Ware Shoals, SC			X
Rogers	Manchester, CT	X		
Schenectady Chemicals	Oyster Creek, TX	X		
	Rotterdam Junction, NY	X		
	Schenectady, NY	X		
Scher Brothers	Clifton, NJ		X	X
Scott Paper	Chester, PA		X	X
	Everett, WA		X	
	Fort Edward, NY		X	
	Marinette, WI		X	
	Mobile, AL		X	X
Shanco Plastics & Chemicals	Tonawanda, NY	X		
The Sherwin-Williams Company	Chicago, IL		X	
	Cleveland, OH		X	X
	Morrow, GA		X	X
	Newark, NJ		X	X

Table 15-6 (Continued)

Producer	Location	Type of Resin Produced Phenolic	Urea	Melamine
Simpson Timber	Arcata, CA	X		
	Portland, OR	X		
Southeastern Adhesives	Lenoir, NC		X	
Spaulding Fibre	De Kalb, IL	X		
	Tonawanda, NY	X		
Sun Chemical	Chester, SC		X	X
Sybron	Haledon, NJ		X	X
Synthron	Ashton, RI		X	X
	Morganton, NC		X	X
Thomason Industries	Fayetteville, NC		X	
	Thomasville, NC		X	
TRW	Dowington, PA	X		
Union Camp	Valdosta, GA	X		
Union Carbide	Bound Brook, NJ	X		
	Elk Grove, CA	X		
	Marietta, OH	X		
	Sacramento, CA	X		
	Texas City, TX	X		
United-Erie	Erie, PA	X	X	
United Merchants & Manufacturers	Langley, SC		X	X
U.S. Oil	East Providence, RI		X	X
	Rock Hill, SC		X	X
Univar	Eugene, OR	X	X	
	Newark, OH	X	X	X
	Portland, OR	X	X	X
	Richmond, CA	X	X	X
USM	Greenville, SC		X	X
Valentine Sugars	Lockport, LA	X		
West Coast Adhesives	Portland, OR	X	X	

Table 15-6 (concluded)

Producer	Location	Type of Resin Produced		
		Phenolic	Urea	Melamine
Westinghouse Electric	Manor, PA	X		
	Hampton, SC	X		
West Point-Pepperell	Opelika, AL		X	X
Weyerhaeuser	Longview, WA	X		
	Marshfield, WI	X		

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[a] See ref. 1.

[b] Plant to be owned by Libby Owens Ford.

Table 15-7. Formaldehyde End-Use Emission Factors

End-Use	lb Formaldehyde Lost per lb Used						
	Process	Level[a]	Storage	Level	Fugitive	Level	Total
Resins[b]	0.00400	D	0.0005	D	0.0005	D	0.00500
Butanediol	0.00200	D	0.0005	D	0.0005	D	0.00300
Pentaerythritol	0.00731	C	0.00088	C	0.00041	C	0.00860[c]
Hexamethylene tetramine	0.00105	C	0.00015	C	0.00030	C	0.00150[c]
Trimethylolpropane	0.00020	B	0.00003	B	0.00003	B	0.00026[d]

[a] A - Basis: site visit data.
B - Basis: state air files.
C - Basis: published literature.
D - Basis: Hydroscience estimate.

[b] Urea, melamine, phenolic and acetal.

[c] See ref. 5.

[d] See ref. 6.

Table 15-8. Formaldehyde Chemical Intermediate Users

Source	Location	1978 Estimated Formaldehyde Consumption (lb X 10^6)	Geographic Coordinates Latitude/Longitude
		Butanediol Production	
Du Pont Company	Houston, TX	240	29 42 04/95 02 05
GAF Corporation	Calvert City, KY	80	37 02 50/88 21 12
	Texas City, TX	80	29 25 29/94 58 07
Total		400	
		Acetal Resins Production	
Celanese Corporation	Bishop, TX	310	27 34 06/97 49 27
Du Pont Company	Parkersburg, WV	140	39 15 27/81 32 52
Total		450	
		Pentaerythritol Production	
Celanese Corporation	Bishop, TX	160	27 34 06/97 49 27
Hercules, Inc.	Louisiana, MO	100	39 26 24/91 03 37
IMC (CSC)	Seiple, PA	50	40 38 12/75 31 58
Perstorp AB	Toledo, OH	70	41 42 33/83 30 00
Total		380	

Table 15-8 (concluded)

Source	Location	1978 Estimated Formaldehyde Consumption (lb X 10^6)	Geographic Coordinates Latitude/Longitude
	Hexamethylenetetramine Production		
Borden, Inc.	Fayetteville, NC	60	35 01 43/78 51 41
W. R. Grace & Co.	Nashua, NH	60	42 46 00/71 27 52
Occidental Petroleum Co.	North Tonawanda, NY	50	43 02 47/78 51 44
Plastics Engineering Co.	Sheboygan, WI	20	43 45 00/87 47 00
Tenneco, Inc.	Fords, NJ	40	40 30 50/74 19 17
Wright Chemical Corp.	Acme, NC	60	34 19 22/78 12 09
Total		290	
	Trimethylolpropane Production		
Celanese Corp.	Bishop, TX	80	27 34 06/97 49 27
Total		80	

Table 15-9. Formaldehyde Emissions from Chemical Intermediate Users

Source	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Butanediol producers						
Du Pont Company	Houston, TX	480,000	120,000	120,000	720,000	10.37
GAF Corporation	Calvert City, KY	160,000	40,000	40,000	240,000	3.46
	Texas City, TX	160,000	40,000	40,000	240,000	3.46
Total		800,000	200,000	200,000	1,200,000	
Acetal resin producers						
Celanese Corporation	Bishop, TX	391,409	48,927	48,927	489,263	7.04
Du Pont Company	Parkersburg, WV	560,000	70,000	70,000	700,000	10.08
Total		951,409	118,927	118,927	1,189,263	
Pentaerythritol producers						
Celanese Corporation	Bishop, TX	369,208	44,445	20,708	434,361	6.25
Hercules, Incorporated	Louisiana, MO	731,000	88,000	41,000	860,000	12.38
IMC (CSC)	Seiple, PA	365,500	44,000	20,500	430,000	6.19
Perstorp AB	Toledo, OH	511,700	61,600	28,700	602,000	8.67
Total		1,977,408	238,045	110,908	2,326,361	

Table 15-9 (concluded)

Source	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Hexamethylenetetramine producers						
Borden, Incorporated	Fayetteville, NC	63,000	9,000	18,000	90,000	1.30
W. R. Grace & Company	Nashua, NH	63,000	9,000	18,000	90,000	1.30
Occidental Petroleum Company	North Tonawanda, NY	52,500	7,500	15,000	75,000	1.08
Plastics Engineering Company	Sheboygan, WI	21,000	3,000	6,000	30,000	0.43
Tenneco, Incorporated	Fords, NJ	42,000	6,000	12,000	60,000	0.86
Wright Chemical Corporation	Acme, NC	63,000	9,000	18,000	90,000	1.30
Total		304,500	43,500	87,000	435,000	
Trimethylolpropane producers						
Celanese Corporation	Bishop, TX	5,050	757	757	6,565	0.09
Total		5,050	757	757	6,565	

---

[a] Based on emission factors shown in Table 7.

[b] Based on 8760 hr/yr operation.

[c] See ref. 9.

[d] See ref. 7.

Formaldehyde emissions from butanediol production are estimated to be 1.20 million lb, from acetal resins 1.19 million lb, from pentaerythritol 2.33 million lb from hexamethylene tetramine 0.44 million lb, and from trimethylol propane 6.5 thousand lb.

Emissions from all other uses of formaldehyde are estimated to be 5.86 million lb. This was estimated by using a weighted average emission factor derived from all other formaldehyde uses.

Specific source locations could not be identified for UF concentrates and chelating agents. Other uses of formaldehyde are so numerous and widespread that a regional breakdown is not possible.

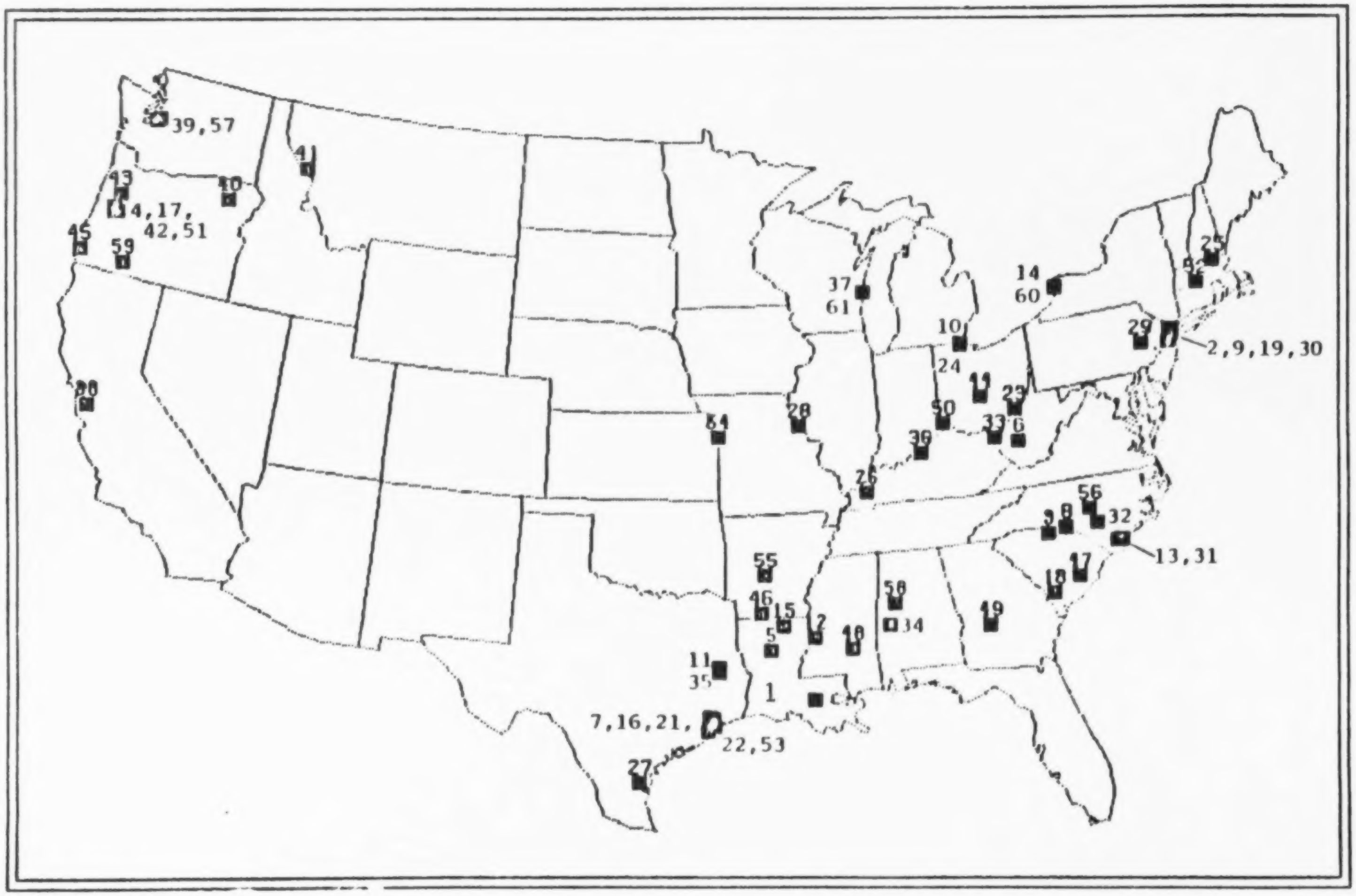
Emissions from exports are assumed to be negligible.

Total nationwide emissions of formaldehyde from all sources are estimated to be 30.27 million lb. A tabulation of the losses is shown in Table 15-10.

Table 15-10. 1978 Formaldehyde Nationwide Emissions

Source	Nationwide Formaldehyde Emissions (million lb/yr)
Production	1.94
Urea resins	8.15
Phenolic resins	7.80
Melamine resins	1.35
Butanediol	1.20
Acetal resins	1.19
Pentaerythritol	2.33
Hexamethylenetetramine	0.44
Trimethylolpropane	0.006
Other miscellaneous*	5.86
Export	0
Total	30.27

*Based on weighted average of all other formaldehyde uses. (0.00481 lb lost/lb used)


39,57
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4,17,
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15
5
11
35
1
7,16,21,
22,53
27

FIGURE 15-1. SPECIFIC POINT SOURCES OF FORMALDEHYDE EMISSIONS

Table 15-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF FORMALDEHYDE

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	BORDEN	GEISMAR, LA	30 13 00	091 01 00	13970	1	1	.675355	.053279	.106561
2	CELANESE	NEWARK, NJ	40 43 30	074 07 25	94741	1	1	.475203	.061920	.097920
3	CELANESE	ROCK HILL, SC	34 57 25	080 57 32	93804	1	1	.475203	.061920	.097920
4	CHEMBOND	SPRINGFIELD, OR	44 02 60	122 59 06	24221	1	1	.604801	.079202	.123839
5	CHEMBOND	WINNIFIELD, LA	31 54 49	092 40 35	13942	1	1	.282239	.037440	.057601
6	DUPONT	BELLE, WV	38 13 06	081 34 12	12866	1	1	1.350710	.106561	.211679
7	DUPONT	LAPORTE, TX	29 42 04	095 02 05	12906	1	1	.863997	.067681	.135360
8	DUPONT	HEALING SPRINGS, NC	35 01 56	080 10 30	13714	1	1	.596144	.047520	.093601
9	DUPONT	LINDEN, NJ	40 36 02	074 12 08	94741	1	1	.433441	.034560	.067681
10	DUPONT	TOLEDO, OH	41 39 22	083 33 20	94830	1	1	.728628	.057601	.113759
11	GEORGIA-PACIFIC	LUFKIN, TX	31 21 00	094 47 00	93987	1	1	0.	.053279	.083520
12	GULF OIL	VICKSBURG, MS	32 17 00	090 54 00	13956	1	1	.243360	.031680	.050400
13	HERCULES	WILMINGTON, NC	34 19 09	077 59 23	13713	1	1	.272159	.021600	.043201
14	HOOKER	TONAWANDA, NY	43 02 47	078 51 44	14747	1	1	.365772	.028800	.057601
15	IMC	STERLINGTON, LA	32 43 35	092 08 56	13942	1	1	.083520	.007200	.012960
16	MONSANTO	CHOCOLATE BAYOU, TX	29 14 55	095 12 45	12906	1	1	.096585	.007317	.016098
17	PACIFIC RESINS	EUGENE, OR	44 01 00	123 05 05	24221	1	1	.256320	.020160	.040319
18	REICHHOLD	HAMPTON, SC	32 53 33	081 06 10	03820	1	1	.135360	.010080	.021600
19	TENNECO	GARFIELD, NJ	40 52 28	074 06 47	94741	1	1	.272159	.021600	.043201
21	DUPONT	HOUSTON, TX	29 42 04	095 02 05	12906	2	2	6.912100	1.727993	1.727993
22	GAF	TEXAS CITY, TX	29 25 29	094 58 07	12923	2	2	2.304002	.576008	.576008
23	DUPONT	PARKERSBURG, WV	39 15 27	081 32 52	13866	3	3	8.064117	1.007991	1.007991

Table 15-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF FORMALDEHYDE (continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
24	PERSTORP	TOLEDO, OH	41 43 10	083 31 28	94830	4	4	7.368404	.887050	.413274
25	W.R. GRACE	NASHUA, NH	42 46 00	071 27 52	14745	5	5	.907185	.129601	.259199
26	GAF	CALVERT CITY, KY	37 02 50	088 21 12	03816	6	1	.407534	.053279	.083520
27	CELANESE	BISHOP, TX	27 34 06	097 49 27	12925	7	2	2.304002	.0576008	.576008
							1	1.271563	.100913	.200675
							3	5.629756	.703735	.703735
							4	5.310439	.639269	.297844
28	HERCULES	LOUISIANA, MO	39 26 24	091 03 37	93989	8	6	.072641	.010896	.010896
							1	.460807	.036000	.072000
29	IMC	SEIPLE, PA	40 38 12	075 31 38	14737	8	4	10.526382	1.267187	.590405
							1	.177118	.014400	.027360
30	TENNECO	FORDS, NJ	40 30 50	074 19 17	94741	9	4	5.263191	.633593	.295199
							1	.617770	.067678	.113759
31	WRIGHT	RIEGELWOOD, NC	34 19 22	078 12 09	13717	9	5	.604801	.086400	.172799
							1	.322552	.041759	.066239
32	BORDEN	FAYETTEVILLE, NC	35 01 43	078 51 41	13714	10	5	.907185	.129601	.259199
							1	.633593	.050400	.099359
							3	1.522355	.190081	.190081
33	ALLIED	SOUTH POINT, OH	38 25 43	082 36 00	93824	11	5	.907185	.129601	.259199
							1	.836631	.066239	.131041
34	BORDEN	DEMOPOLIS, AL	32 30 48	087 50 06	13850	11	3	.647990	.080927	.080927
							1	.272159	.021600	.043201
							3	1.522355	.190081	.190081

Table 15-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF FORMALDEHYDE (continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
35	BORDEN	DIBOLL, TX	31 11 52	094 46 50	93987	11	1	.214561	.017280	.033121
							3	.803494	.100799	.100799
36	BORDEN	LOUISVILLE, KY	38 12 09	085 51 49	93820	11	1	.214561	.017280	.033121
							3	.803494	.100799	.100799
37	BORDEN	SHERBOYGAN, WI	43 45 26	087 46 17	14898	11	1	.351344	.027360	.054718
							3	1.522355	.190081	.190081
38	BORDEN	FREEMONT, CA	37 32 06	121 57 24	23244	11	1	.607686	.047520	.095041
							3	1.366565	.171360	.171360
39	BORDEN	KENT, WA	47 23 12	122 13 15	24238	11	1	.214561	.017280	.038121
							3	1.522355	.190081	.190081
40	BORDEN	LARGRANDE, OR	45 20 33	118 02 02	24130	11	1	.174239	.012960	.027360
							3	1.366565	.171360	.171360
41	BORDEN	MISSOULA, MT	46 54 10	114 40 00	24146	11	1	.241920	.018720	.037440
							3	1.366565	.171360	.171360
42	BORDEN	SPRINGFIELD, OR	44 02 60	122 59 06	24221	11	1	.649448	.050400	.102239
							3	1.522355	.190081	.190081
43	GEORGIA-PACIFIC	ALBANY, OR	44 37 07	123 05 13	24232	11	1	.486714	.063359	.099359
							3	1.522355	.171360	.171360
44	GEORGIA-PACIFIC	COLUMBUS, OH	39 53 07	082 56 45	14821	11	1	.407534	.053279	.083520
							3	1.522355	.171360	.171360
45	GOERGIA-PACIFIC	COOS BAY, OR	42 27 26	124 10 47	24283	11	1	.367199	.048960	.074879
							3	1.522355	.171360	.171360

Table 15-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF FORMALDEHYDE (continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
46	GEORGIA-PACIFIC	CROSSET, AR	33 08 36	093 02 11	93992	11	1	0.	.053279	.093601
							3	1.522355	.171360	.171360
47	GEORGIA-PACIFIC	RUSSELVILLE, SC	33 20 52	079 58 00	13717	11	1	.807839	.106561	.165601
							3	1.522355	.171360	.171360
48	GEORGIA-PACIFIC	TAYLORSVILLE, MS	31 51 00	089 25 00	13865	11	1	.486714	.063359	.099359
							3	1.522355	.171360	.171360
49	GEORGIA-PACIFIC	VIENNA, GA	32 07 30	083 49 00	13815	11	1	0.	.021600	.043201
							3	1.522355	.171360	.171360
50	MONSANTO	ADDYSTON, OH	39 07 30	084 42 58	93815	11	1	.048571	.004286	.007143
							3	.718861	.089856	.089856
51	MONSANTO	EUGENE, OR	44 09 59	123 08 19	24221	11	1	.048571	.004286	.007143
							3	1.522355	.190081	.190081
52	MONSANTO	SPRINGFIELD, MA	42 09 33	072 29 09	14763	11	1	.146342	.011707	.023415
							3	1.522355	.190081	.190081
53	REICHHOLD	HOUSTON, TX	29 45 10	095 10 15	12906	11	1	.486714	.063359	.099359
							3	.647990	.080927	.080927
54	REICHHOLD	KANSAS CITY, KA	39 09 28	094 37 41	13988	11	1	.135360	.010080	.021600
							3	.718861	.089856	.089856
55	REICHHOLD	MALVERN, AR	34 24 09	092 48 45	13963	11	1	.446410	.059040	.092161
							3	1.522355	.190081	.190081
56	REICHHOLD	MONCURE,NC	35 31 18	079 04 52	13714	11	1	.486714	.063359	.099359
							3	1.366565	.171360	.171360

Table 15-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF FORMALDEHYDE (concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
57	REICHHOLD	TACOMA, WA	47 16 11	122 22 57	24207	11	1	.203041	.027359	.041759
							3	1.522355	.190081	.190081
58	REICHHOLD	TUSCALOOSA, AL	33 12 03	087 34 00	13825	11	1	.188638	.014400	.030240
							3	1.522355	.190081	.190081
59	REICHHOLD	WHITE CITY, OR	42 26 18	122 07 07	24225	11	1	1.012335	.133920	.207360
							3	1.522355	.190081	.190081
60	OCCIDENTAL	NORTH TOWAWANDA, NY	43 02 47	078 51 44	14747	12	3	.718829	.089856	.089856
							5	.755993	.108000	.216001
61	PLASTICS	SHEBOYGAN, WI	43 45 00	087 47 00	14898	12	3	.874366	.109440	.109440
							5	.802400	.043201	.086400

[a] One emission point has been eliminated due to comments to early drafts of this document.

TABLE 15-11 (Concluded)

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* Plant Types:

Type 1: Plant produces formaldehyde
Type 2: Plant produces butanediol
Type 3: Plant produces acetal resins
Type 4: Plant produces pentaerythritol
Type 5: Plant produces hexamethyl tetramine
Type 6: Plant produces formaldehyde and butanediol
Type 7: Plant produces formaldehyde, acetal resins, pentaerythritol and trimethylol propane
Type 8: Plant produces formaldehyde and pentaerythritol
Type 9: Plant produces formaldehyde and hexamethyl tetramine
Type 10: Plant produces formaldehyde, hexamethyl tetramine, and resins
Type 11: Plant produces formaldehyde and resins
Type 12: Plant produces hexamethyl tetramine and resins

† Source Types:

Type 1: Formaldehyde production
Type 2: Butanediol production
Type 3: Resins production
Type 4: Pentaerythritol production
Type 5: Hexamethylene tetramine production
Type 6: Trimethylol propane production

Table 15-12. EXPOSURE AND DOSAGE OF FORMALDEHYDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
100	11	1,110
50	330	21,800
25	1,556	63,600
10	7,437	152,000
5	19,909	238,000
2.5	51,751	351,000
1	165,115	513,000
0.5	392,328	667,000
0.25	887,638	836,000
0.1	2,335,139	1,060,000
0.05	4,242,104	1,190,000
0.025	7,398,887	1,300,000
0.01	14,018,225	1,410,000
2.45×10^{-4}*	27,458,135	1,480,000

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*The lowest annual average concentration occurring within 20 km of the specific point source

TABLE 15-13. EMISSIONS RATES AND NUMBER OF GENERIC POINT SOURCES OF FORMALDEHYDE (RESINS PRODUCTION)*

Region	Emissions/Site (gm/sec)	Number of Sites
New England	1.233	14
Middle Atlantic	1.233	39
East North Central	1.233	47
West North Central	1.233	7
South Atlantic	1.233	28
East South Central	1.233	12
West South Central	1.233	15
Mountain	1.233	0
Pacific	1.233	23

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* Those resin production units located within plants that are also equipped with other formaldehyde-emitting facilities were treated as specific point sources. Plants that only emit formaldehyde from phenolic/urea/melamine resin production units are treated here with average emissions rate of 1.233 gm/sec per unit.

Average emissions parameters for process vent, storage vent, and fugitive emissions weighted by their emissions rates are:

Vent height: 50 m
Building cross section: 50 m^2
Vent diameter: 0.10 m
Vent velocity: 4.8 m/sec
Vent temperature: 325°K

TABLE 15-14. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF FORMALDEHYDE (RESINS PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
2.5	85	264
1	755	1,180
0.5	2,730	2,520
0.25	--	3,760
0.1	--	5,440
0.05	--	7,300
0.025	--	9,200
0	--	11,400

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 15-15. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF FORMALDEHYDE

Parameter	Value
Daytime decay rate (K_d)	4.2 x 10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	84.4 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 15-16. FORMALDEHYDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level (μg/m^3)	Population (person)	Dosage (ug/m^3/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.250000	505140	225625.1	0.	100.0	0.	100.0	0.	0.
.100000	9149730	1653960.0	0.	100.0	0.	100.0	0.	0.
.050000	27819254	2998265.2	0.	100.0	0.	100.0	0.	0.
.025000	73231345	4503453.5	0.	100.0	0.	100.0	0.	0.
.010000	141027899	5698572.7	0.	100.0	0.	97.9	.7	1.3
0.	158679135	5817783.3	0.	100.0	0.	93.9	2.6	3.6
						92.6	2.7	4.7

TABLE 15-17 EXPOSURE AND DOSAGE SUMMARY OF FORMALDEHYDE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	11	0	0	11	1,110	0	0	1,110
50	330	0	0	330	21,800	0	0	21,800
25	1,556	0	0	1,556	63,600	0	0	63,600
10	7,437	0	0	7,437	152,000	0	0	152,000
5	19,909	0	0	19,909	238,000	0	0	238,000
2.5	51,751	85,000	0	136,751	351,000	264,000	0	615,000
1	165,115	755,000	0	920,115	513,000	1,180,000	0	1,693,000
0.5	392,328	2,730,000	0	31,122,328	667,000	2,520,000	0	3,187,000
0.25	887,638	--	505,140	--	836,000	3,760,000	225,625	4,821,625
0.1	2,335,139	--	9,149,730	--	1,060,000	5,440,000	1,653,960	8,153,960
0.05	--	--	27,819,254	--	--	7,300,000	2,998,265	--
0.01	--	--	73,231,345	--	--	9,200,000	4,503,455	--
0	--	--	141,027,899	--	--	--	3,698,573	--
	27,458,135	--	158,679,135	--	1,480,000	11,400,000	5,817,783	18,697,793

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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2. R. J. Lovell, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry---Formaldehyde Product Report (on file at EPA, ESED, Research Triangle Park, NC) October 1978.

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6. Celanese Chemical Co., Bishop, TX, Texas Air Control Board Emission Inventory Questionnaire for 1975, Trimethylolpropane Process.

7. Celanese Chemical Co., (R.H. Maurer) personal communication in response to publication of the first draft of this report (July 1981).

8. Formaldehyde Institute (Donald L. Morgan) personal communication in response to publication of the first draft of this report (May 1981).

9. BASF Wyandate Corporation (Keith Fry) personal communication in response to publication of the first draft of this report (October 1980).

10. Monsanto Company (C.D. Malloch) personal communication in response to publication publication of the second draft of this report (July 1982).

APPENDIX A-16 ----- Hexachlorocylopentadiene

HEXACHLOROCYCLOPENTADIENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number:

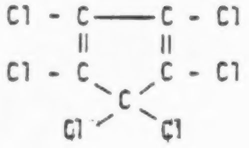
Synonyms: Perchlorocyclopentadiene

Chemical Formula

Molecular Weight: 272.77

Molecular Formula: C_5Cl_6

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid

Boiling Point: 239°C

Melting Point: 9°C

Density: 1.702 at 25°C/4°C

Vapor Pressure:

Vapor Density:

Solubility:

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors:

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Hexachlorocyclopentadiene has been produced commercially by three different processes. It is believed that currently in the United States, the predominant method involves the use of mixed pentanes as a raw material. The mixed pentanes are chlorinated to polychlorinated pentanes in the liquid phase followed by vapor phase chlorinolysis and ring closure over a surface-active catalyst to produce hexachlorocyclopentadiene.[1,2]

Two companies at three locations currently produce hexachlorocyclopentadiene in the United States.[3] The locations of individual plants are shown in Table 16-1. An estimated 7 million lb of hexachlorocyclopentadiene was produced in 1978.

B. USES

Hexachlorocyclopentadiene is used as a chemical intermediate in the manufacture of flame retardants, in the manufacture of pesticides, and in the production of flame-retardant resins.

A list of the major hexachlorocyclopentadiene derivatives is shown in Table 16-2.[4] Current production estimates of hexachlorocyclopentadiene derivatives are not available The known locations of hexachlorocyclopentadiene users are shown in Table 16-3.[4]

Hexachlorocyclopentadiene has a very questionable future because many of its former end-uses have been banned by EPA and OSHA regulations.

II. EMISSION ESTIMATES

A. PRODUCTION

Estimated emission losses from the production of hexachlorocyclopentadiene are shown in Table 16-4 for each of the three producing locations. Total emissions of hexachlorocyclopentadiene resulting from its production are estimated to have been 56,000 lb in 1978. Emissions were determined using the emission factor shown in Table 16-4 which represents Hydroscience's estimate of the average emis-

Table 16-1. Production of Hexchlorocyclopentadiene[a]

Source	Location	1978 Estimated Production[b] (M lb)	1978 Estimated Capacity (M lb)	Geographic Coordinates Latitude/Longitude
Hooker Chemical & Plastics Corp.	Montague, MI	1.75	NA[c]	43 24 45/86 22 30
	Niagara Falls, NY	3.50	NA	43 04 52/79 00 34
Velsicol Chemical Corp.	Memphis, TN	1.75	NA	35 09 50/90 57 45
Total		7[d]	NA	

[a] See ref. 3.

[b] Individual site production allocated by the ratio of the total number of employees at each site compared to the total number of employees at all three sites.

[c] Not available.

[d] Hydroscience estimate.

Table 16-2. Hexachlorocyclopentadiene Derivatives*

Compound	End-Use Category	1974 Production (million lb)	1978 Status	Known Producer	Location
Aldrin	Pesticide	6.5	No longer made		
Chloradane	Pesticide	21.2	?	Velsicol	Marshall, IL
Dieldrin	Pesticide	1.0	No longer made		
Endosulfan	Pesticide	1.5	?	FMC & Hooker	New York sites
Endrin	Pesticide	1.2	No longer made		
Heptachlor	Pesticide	2.0	?	Velsicol	Memphis, TN
Pentac®	Pesticide	?	No longer made		
Het-acid	Flame retardant	?	?	Hooker	Niagara Falls, NY
Mivex	Pesticide	?	No longer made		
Het-anhydride	Flame retardant	7.0	?	Hooker	Niagara Falls, NY
Dichlorane plus	Flame retardant	?	?	Hooker	Niagara Falls, NY
Chlorendic diesters	Resins	?	?	Velsicol	Memphis, TN

*See ref. 1 and 4.

Table 16-3. Consumers of Hexachlorocyclopentadiene[a]

Company	Location	End-Use[b]	Geographic Coordinates Latitude/Longitude
Hooker	Montague, MI	A	43 24 45/86 22 30
	Niagara Falls, NY	A,B	43 04 52/79 00 34
Velsicol	Memphis, TN	B,C	35 09 50/90 57 45
	Marshall, IL	A	39 23 00/87 42 30
FMC	Middleport, NY	A	43 12 21/78 29 23

[a] See ref. 4.

[b] End-use code:
A = pesticide
B = flame retardent
C = resin

Table 16-4. 1978 Hexachlorocyclopentadiene Production Emissions

Company	Location	Process Emissions		Storage Emissions		Fugitive Emissions		Total Emissions[a]	
		(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]
Hooker	Montague, MI	9,100	0.131	1,400	0.020	3,500	0.050	14,000	0.202
	Niagara Falls, NY	18,200	0.262	2,800	0.040	7,000	0.101	28,000	0.404
Velsicol	Memphis, TN	9,100	0.131	1,400	0.020	3,500	0.050	14,000	0.202
Total		36,400		5,600		14,000		56,000	

[a] Emission factor hexachlorocyclopentadiene (lb lost/lb produced)

Process	0.0052	D - Hydroscience estimate
Storage	0.0008	D - Hydroscience estimate
Fugitive	0.0020	D - Hydroscience estimate
Total	0.0080	

[b] Based on 8760 hr/yr operation.

sion loss for the synthetic organic chemical industry. Other associated components include pentanes, polychlorinated pentanes, and hydrogen chloride.

Process emissions originate primarily from the chlorination reactor vent. Storage emissions represent the losses from both in-process and final product storage tanks as well as loading and handling. Fugitive emissions are those emissions resulting from plant equipment leaks. Vent parameter data are shown in Table 16-5.

B. USE

Total emissions of hexachlorocyclopentadiene resulting from its use as a chemical intermediate are estimated to have been 3500 lb in 1978 using an emission factor of 0.0005 lb lost/lb produced.[5] This factor was determined from hexachlorocyclopentadiene use in pesticide manufacturing and is considered representative of its use as a chemical intermediate. Vent parameter data for end-uses are shown in Table 16-5.

Source locations of end-use emissions are shown in Table 16-6. Total emissions were distributed by ratioing the total number of plant employees employed at each site to the total number employees at all five sites.

The total nationwide emissions of hexachlorocyclopentadiene in 1978 from all sources are shown in Table 16-7 and are estimated to have been 59,500 lb.

Table 16-5. Hexachlorocyclopentadiene Vent Parameters[a]

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[b,c]					
Process	2	40	0.17	140	20
Storage	6	20	0.17	80	
End-use[b,c]					
Process	1	40	0.17	100	20
Storage	2	20	0.17	80	

[a] Hydroscience estimate.

[b] Fugitive emissions are dispersed over a 200 ft X 200 ft area.

[c] Building cross-section - 100 m^2.

Table 16-6. 1978 Hexachlorocyclopentadiene End-Use Emissions

Source	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Hooker	Montague, MI	570	90	215	875	0.013
	Niagara Falls, NY	810	125	315	1250	0.018
Velsicol	Memphis, TN	390	60	150	600	0.009
	Marshall, IL	180	25	70	275	0.004
FMC	Middleport, NY	325	50	125	500	0.007
Total		2275	350	875	3500	

[a] Emission factor for hexachlorocyclopentadiene end-use (lb lost/lb used). See ref. 5.

Process	0.000325	C - Derived from published source
Storage	0.000050	C - Derived from published source
Fugitive	0.000125	C - Derived from published source
Total	0.000500	

[b] Based on 8760 hr/yr operation.

Table 16-7. 1978 Hexachlorocyclopentadiene Nationwide Emissions

Source	Estimated National Emission (lb/yr)
Production	56,000
Chemical intermediates	3,500
Pesticides	
Flame retardents	
Resins	
Total	59,500

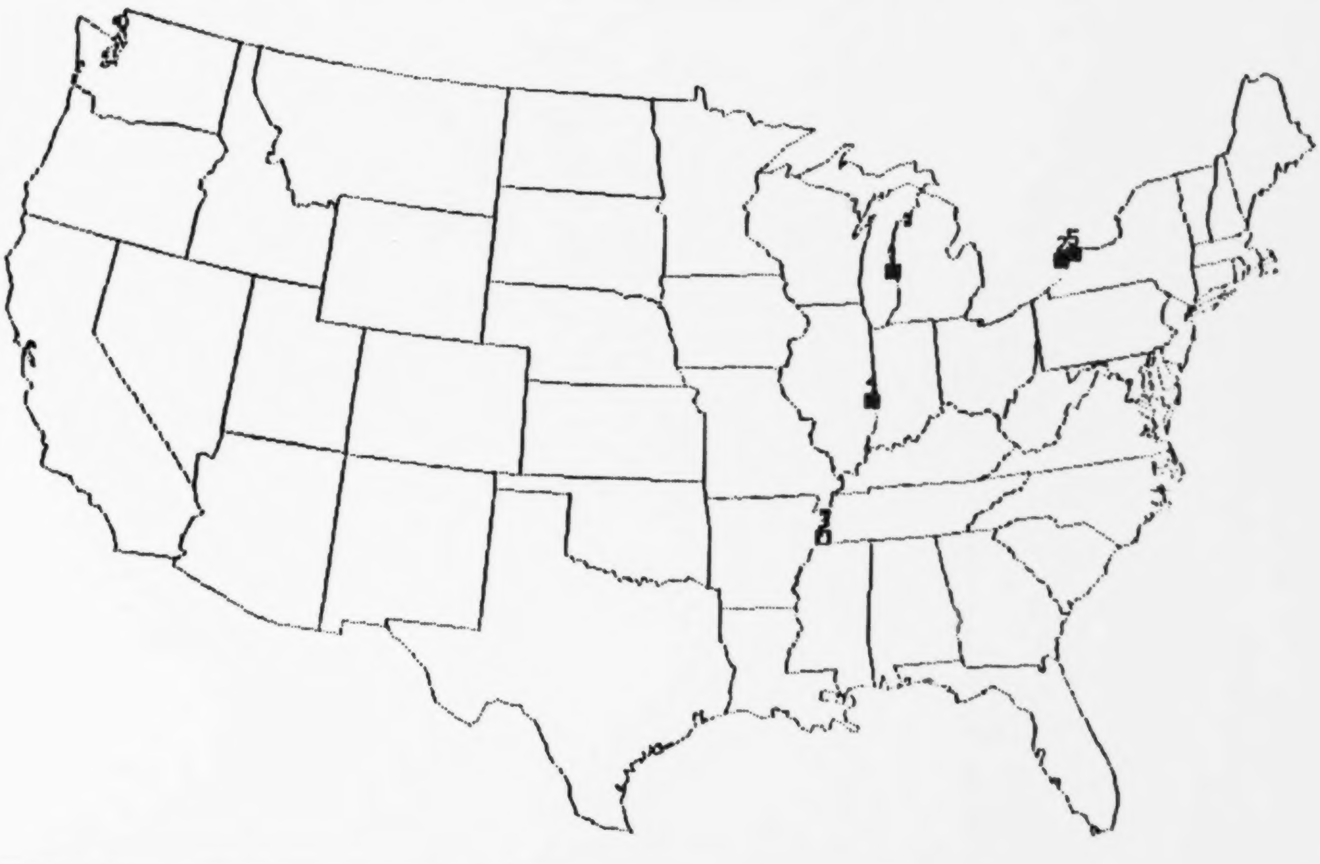


FIGURE 16-1. SPECIFIC POINT SOURCES OF HEXACHLOROCYCLOPENTADIENE EMISSIONS

TABLE 16-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF HEXACHLOROPENTADIENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC) PROCESS	EMISSIONS (GM/SEC) STORAGE	EMISSIONS (GM/SEC) FUGITIVE
1	HOOKER	MONTAGUE, MI	43 24 45	086 22 30	14840	1	1	.131040	.020160	.050400
							2	.008200	.001296	.003096
2	HOOKER	NIAGRA FALLS, NY	43 03 02	079 00 27	14747	1	1	.262080	.040320	.100800
							2	.011664	.001800	.004536
3	VELSICOL	MEMPHIS, TN	35 09 50	089 57 45	13963	1	1	.131040	.020160	.050400
							2	.005616	.000864	.002160
4	VELSICOL	MARSHALL, IL	39 23 00	087 42 30	93819	2	2	.002592	.000360	.001008
5	FMC	MIDDLEPORT, NY	43 12 21	078 29 23	14747	2	2	.004680	.000720	.001800

* Plant Types:

Type 1: Plant produces and consumes hexachlorocyclopentadiene

Type 2: Plant consumes hexachlorocyclopentadiene

† Source Types:

Type 1: Hexachlorocyclopentadiene production

Type 2: Hexachlorocyclopentadiene consumption

TABLE 16-9. EXPOSURE AND DOSAGE OF HEXACHLOROCYCLOPENTADIENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
10	1	12
5	6	53
2.5	149	494
1	685	1,290
0.5	1,584	1,870
0.25	4,291	2,790
0.1	17,399	4,710
0.05	51,677	7,080
0.025	128,051	9,730
0.01	319,577	12,700
0.005	623,040	14,800
1.6×10^{-5}*	1,376,988	16,700

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. J. E. Stevens, "Chlorinated Derivatives of Cyclopentadiene," p. 791 in Kirk-Othmer Encyclopedia of Chemical Technology, 3d ed., Vol. 5, edited by M. Grayson et al., Wiley, New York, 1979.

2. R. R. Whetstone, "Chlorinated Derivatives of Cyclopentadiene," p. 240 in Kirk-Othmer Encyclopedia of Chemical Technology, 2d ed., Vol. 5, edited by A. Standed et al., Wiley, New York, 1967.

3. 1979 Directory of Chemical Producers, United States of America, Stanford Research Institute, Menlo Park, CA.

4. J. Hayers and O. H. Johnson, "Insecticides," pp. 573.3007E,F, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (July 1976).

5. Source Assessment: Pesticide Manufacturing Air Emissions——Overview and Prioritization, EPA, IERL, ORD, EPA-600/2-78-004d, Research Triangle Park, NC (March 1978).

APPENDIX A-17 ----- Manganese

MANGANESE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number:

Synonyms: None

Chemical Formula

Molecular Weight: 54.94 (atomic wt.)

Molecular Formula: Mn - atomic number 25

Molecular Structure: (atomic structure)

δ & α - Form: Body centered cubic
β - Form: Cubic
γ - Form or electrolytic MN: Face centered cubic

Chemical and Physical Properties

Physical State at STP: Solid-metal-steel gray, lustrous, hard, brittle

Boiling Point: 1962°C

Melting Point: 1244°C

Density: 7.21 to 7.44 (depending on alotropic form)

Vapor Pressure: N/A

Vapor Density: N/A

Solubility: Insoluble

Log Partition Coefficient (Octanol/H_2O): N/A

Atmospheric Reactivity

Transformation Products: No atmospheric transformation (aerosol and particle deposition). Reacts with all mineral acids with evolution of hydrogen and formation of divalent manganous salts.

Reactivity Toward OH·: N/A

Reactivity Toward O_3: N/A

Reactivity Toward Photolysis: N/A

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

There was neither production nor shipments of manganese ore containing 35% or more manganese by weight in the United States in 1976, the last year for which complete data are available.[1]

U.S. production from domestic low grade (less the 35% manganese) ores mined in Minnesota and New Mexico is estimated to have been 81,607 tons.[1] Imports supplied the major portion of manganese ore used in the United States amounting to a total of 1,519,266 tons. Total consumption of manganese ore is estimated to have been 1,600,873 tons.[1]

B. USES

Manganese ore consumption is shown in Table 17-1.[1] The largest end-use of manganese ore is for the direct manufacture of manganese alloys and metal, which consumed (1,263,531 tons). Pig iron and steel production consumed an estimated 143,761 ton, or 9%. The remainder (12%) was consumed for battery chemical and miscellaneous alloy manufacture (193,581 tons).

C. INCIDENTAL SOURCES

Incidental sources of manganese emissions include coal- and oil-fired boilers, and coke ovens. The boilers include industrial, electrical utility power plant, commercial, and residential types. Manganese emissions originate as impurities from oil and coal when they are burned in the boilers or in coke ovens Table 17-2[1,2] shows the estimated consumption of oil and coal by use category. Table 17-3[4] indicates the percentage breakdown by region of the coal and oil used by electric utility power plants.

II. EMISSION ESTIMATES

A. PRODUCTION

The primary source of emission data for this summary was the Survey of Emissions and Controls for Hazardous and Other Pollutants, prepared for the Environmental Protection Agency by the Mitre Corp.[5] Based on the emissions data presented in

Table 17-1. United States Manganese Ore Consumption[*]

Use	Usage (%)	Manganese Ore Consumed (ton/yr)
Manganese alloys/metals	79	1,263,581
Pig iron and steel	9	143,761
Dry cells, chemicals, misc.	12	193,581
Total	100	1,600,923

[*] See ref. 1.

Table 17-2. 1978 United States Oil and Coal Consumption*

User	Coal Consumption (million tons)	Oil Consumption (million bbls)
Electrical utilities	480	646
Industry	55	671
Coke ovens	75	---
Residential/commercial	8	707
Diesel fuel	---	327
Total	618	2351

*See refs. 2 and 3.

Table 17-3. Electrical Utility Power Plant Locations and Usage of Coal and Oil by Geographic Region*

Region	Number of Coal Consuming sites	Percentage of Total U.S. Coal Consumption	Number of Oil Consuming sites	Percentage of Total U.S. Oil Consumption
New England	9	0.7	35	9.4
Middle Atlantic	51	11.3	70	27.9
East North Central	156	33.9	110	5.9
West North Central	111	9.4	85	0.7
South Atlantic	61	19.6	97	31.4
East South Central	44	16.3	26	2.0
West South Central	3	1.3	100	4.8
Mountain	38	5.8	44	2.2
Pacific	1	0.7	33	15.7
Total	474	100.0	600	100.0

*See ref. 4.

this report and the fact that high grade ore is no longer mined in the United States, manganese emissions from mining are assumed to be negligible.

B. USES

Emissions of manganese from its use as an ore also include incidental emissions inherent in the metals processed. The emissions from its use to produce ferroalloys which include ferromanganese, silicomanganese, and manganese metals are shown in Table 17-4 by geographic region.[6] Emission estimates of 12,632,000 lb were based on an emission factor of 0.003307 lb manganese lost per pound ferroalloy produced.[5] The emission factor is large because it includes ferro- and silicomanganese production which are subsequently consumed to produce ferroalloys. Total ferroalloy production was estimated to be 1,910,000 tons in 1978.

Emissions of manganese from its ore to produce iron and steel are shown in Table 17-5 by geographic region. Estimated emissions of 9,212,000 lb are based on an emission factor of 0.00002 lb manganese lost per pound iron and steel produced and assuming total iron and steel production was 230,300,000 tons in 1978.[5] Total emissions were distributed by the number of people employed in the industry in each region.[7]

Emissions from gray iron foundry operations were estimated to have been 5,540,000 lb based on an emission factor of 0.000154 lb manganese lost per pound of metal produced[5] and production was 18,000,000 ton of hot metal in 1978. The emissions are shown in Table 17-6[7] and were distributed using the same method as for iron and steel.

Manganese emissions from chemical applications were estimated to have been 644,000 lb based on an emission factor of 0.004 lb lost/lb used and assuming 80,500 ton manganese used. Manganese emissions from its use in battery manufacture were estimated to have been 276,000 lb based on an emission factor of 0.004 lb lost/lb used[5] and assuming 34,500 ton manganese used. Emissions from welding rod manufacture of 48,000 lb were taken directly from the report.[5] Actual production quantities of manganese used for this application could not be estimated. Emissions were assumed to be the same as those reported in the Mitre report. Specific source locations for all three of these sources could not be identified to allow for a regional distribution.

Table 17-4. Manganese Emissions from Ferroalloy, Ferro Manganese, and Silica Manganese Production[a]

Region	Number of Sites	Emissions (lb/yr)[b]
New England	0	0
Middle Atlantic	12	2,972,220
East North Central	8	1,981,480
West North Central	1	247,685
South Atlantic	8	1,981,480
East South Central	13	3,219,905
West South Central	1	247,685
Mountain	4	990,740
Pacific	4	990,740
Total	51	12,632,000[c]

[a] See ref. 6.

[b] Based on an emission factor of 0.003307 lb manganese lost per lb ferro alloy produced. "C" derived from published data (see ref. 5).

[c] Average emission rate per site: 247,685 lb/yr (3.57 g/sec).

Table 17-5. Manganese Emissions from Iron and Steel Production[a]

Region	Number of Sites	Manganese Emissions (lb/yr)[b]	Average Emissions per Site	
			(lb/yr)	(g/sec)[c]
New England	10	55,045	5,505	0.079
Middle Atlantic	65	2,846,685	43,795	0.630
East North Central	84	3,859,795	45,950	0.661
West North Central	5	101,260	20,250	0.292
South Atlantic	22	819,940	37,270	0.537
East South Central	25	626,250	25,050	0.361
West South Central	12	211,865	17,655	0.254
Mountain	2	221,210	110,605	1.592
Pacific	32	469,950	14,685	0.211
Total	257	9,212,000	35,844	

[a] See ref. 7.

[b] Based on emission factor of 0.00002 lb manganese lost per lb iron and steel produced. "C" derived from published data (see ref. 5).

[c] Based on 8760 hr/yr operation.

Table 17-6. Manganese Emissions from Gray Iron Foundry Operations[a]

Region	Number of Sites	Manganese Emissions (lb/yr)	Average Emissions per Site (lb/yr)	Average Emissions per Site (g/sec)[b]
New England	13	138,500	10,655	0.15
Middle Atlantic	42	508,985	12,120	0.17
East North Central	129	2,887,725	22,385	0.32
West North Central	29	315,085	10,865	0.16
South Atlantic	22	408,575	18,570	0.27
East South Central	37	654,410	17,685	0.25
West South Central	19	277,000	14,580	0.21
Mountain	5	65,785	13,157	0.19
Pacific	28	283,925	10,140	0.15
Total	324	5,540,000[c]	17,100	

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.000154 lb manganese lost per lb metal produced. "C" derived from published data (see ref. 5).

C. INCIDENTAL SOURCES

Manganese emissions resulting from electrical utility power plants are shown for coal-fired power plants in Table 17-7, and for oil-fired power plants in Table 17-8. Coal-fired plants had manganese emissions of 5,280,000 lb[5] and oil-fired plants 13,566 lb.[5]

These emissions were calculated by multiplying the emission factors shown in Tables 17-7 and 17-8 by the coal and oil used shown in Table 17-2. The emissions were distributed by region according to the usage percentages shown in Table 17-3.

Manganese emissions from coke ovens were estimated to have been 1,950,000 lb as shown in Table 17-9[8] using the emission factor of 0.000013 lb manganese lost per lb of coal used and the amount of coal used is shown in Table 17-2. Total emissions were distributed by the number of sites in each region.

The remaining incidental sources of manganese emissions are from other sources which burn oil or coal. Emissions from coal and oil-fired industrial boilers were estimated to have been 352,000 lb and 14,091 lb respectively derived from an emission factor of 0.0000032 lb manganese lost per lb of coal burned and 0.00000050 lb manganese lost per gal of oil burned.[5] Emissions from residential/ commercial coal and oil for heating were estimated to be 16,000 lb and 4,454 lb respectively derived from an emission factor of 0.0000010 lb manganese lost per lb of coal burned and 0.00000015 lb manganese lost per gal of oil burned.[5]. Source locations for all these incidental sources are considered too numerous and too diverse to pinpoint regional distributions.

Vent parameter data for all manganese sources are shown in Table 17-10.

Table 17-11 presents a summary of manganese emissions. Total nationwide emissions are estimated to have been 35,982,111 lb in 1978.

Table 17-7. Manganese Emissions from Electrical Utility Power Plants (coal-fired)[a]

Region	Number of Sites	Manganese Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	9	36,960	4,105	0.06
Middle Atlantic	51	596,640	11,700	0.17
East North Central	156	1,789,920	11,475	0.17
West North Central	111	496,320	4,470	0.07
South Atlantic	61	1,034,880	16,965	0.25
East South Central	44	860,640	19,560	0.29
West South Central	3	68,640	22,880	0.33
Mountain	38	359,040	9,450	0.14
Pacific	1	36,960	36,960	0.54
Total	474	3,280,000[c]	11,140	

[a] See ref. 3.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.0000055 lb manganese lost per lb coal burned. "C" derived from published data (see ref. 5).

Table 17-8. Manganese Emissions from Electrical Utility Power Plants (oil-fired)[a]

Region	Number of Sites	Manganese Emissions (lb/yr)	Average Emissions per Site	
			(lb/yr)	(g/sec)
New England	35	1,275	36.4	0.0005
Middle Atlantic	70	3,788	54.1	0.0008
East North Central	110	800	7.3	0.0001
West North Central	85	100	1.2	Nil
South Atlantic	97	4,250	43.8	0.0006
East South Central	26	275	10.6	0.0002
West South Central	100	650	6.5	0.0001
Mountain	44	300	6.8	0.0001
Pacific	33	2,125	64.4	0.0009
Total	600	13,566[c]	22.6	

[a] See ref. 3.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.0000005 lb manganese lost per gal oil burned. "C" derived from published data (see ref. 5).

Table 17-9. Manganese Emissions from Coke Oven Operations[a]

Region	Number of Sites	Manganese Emissions (lb/yr)
New England	0	0
Middle Atlantic	15	479,505
East North Central	25	799,185
West North Central	3	95,900
South Atlantic	4	127,870
East South Central	9	287,705
West South Central	2	63,935
Mountain	2	63,935
Pacific	1	31,965
Total	61	1,950,000[b,c]

[a] See ref. 8.

[b] Based on an emission factor of 0.000013 lb manganese lost per lb coal burned. "C" derived from published data (see ref. 5).

[c] Average emission per site: 31,967 lb/yr (0.46 g/sec).

Table 17-10. Manganese Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Power plant	1	400	16	200	90
Iron and steel	2	80	1	200	40
Ferro alloy	1	80	1	200	40
Gray iron foundry	1	150	2	200	40
Coke oven	2	30	1	300	15

Building cross-section all sources - 200 m^2.

Table 17-11. 1978 Manganese Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Mining	Negligible
Iron and steel	9,212,000
Gray iron foundry	5,540,000
Ferro alloy, ferro manganese, silico manganese	12,632,000
Chemical applications	644,000
Battery production	276,000
Welding rod manufacture	48,000
Power Plants	
Coal	5,280,000
Oil	13,566
Industrial Boilers	
Coal	352,000
Oil	14,091
Residential/commercial	
Coal	16,000
Oil	4,454
Coke ovens	1,950,000
Total	35,982,111

TABLE 17-12. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF MANGANESE

Region	Ferroalloys Production		Iron/Steel Production		Gray Iron Foundry		Power Plant (Coal)		Power Plant (Oil)		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	3.567	0	0.0793	10	0.153	13	0.0591	9	0.000524	35	0.460	0
Middle Atlantic	3.567	12	0.631	65	0.174	42	0.168	51	0.000779	70	0.460	15
East North Central	3.567	8	0.662	84	0.322	129	0.165	156	0.000105	110	0.460	25
West North Central	3.567	1	0.292	5	0.156	29	0.0644	111	0.000017	85	0.460	3
South Atlantic	3.567	8	0.537	22	0.267	22	0.243	61	0.000631	97	0.460	4
East South Central	3.567	13	0.361	25	0.255	37	0.282	44	0.000153	26	0.460	9
West South Central	3.567	1	0.254	12	0.210	19	0.329	3	0.0000936	110	0.460	2
Mountain	3.567	4	1.593	2	0.189	5	0.136	38	0.0000979	44	0.460	2
Pacific	3.567	4	0.211	32	0.146	28	0.532	1	0.000927	33	0.460	1

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TABLE 17-13. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF MANGANESE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)							Dosage [$10^3(\mu g/m^3)$ • persons]						
	Iron/ Steel Production	Ferro-alloys Production	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total	Iron/ Steel Production	Ferro-alloys Production	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Oven Coke	U.S. Total
10	11	0	0	0	0	2	13	146	0	0	0	0	28	174
5	105	0	0	0	0	14	119	796	0	0	0	0	102	898
2.5	527	9	0	0	0	50	587	2,180	27	0	0	0	229	2,430
1	1,660	258	0	0	0	219	2,140	3,870	377	0	0	0	483	4,730
0.5	3,960	1,420	137	0.2	0	628	6,150	5,540	1,150	86	0.1	0	754	7,520
0.25	--	--	--	--	--	--	--	7,220	2,000	364	10	0	1,030	10,600
0.1	--	--	--	--	--	--	--	10,200	3,430	1,030	76	0	1,450	16,100
0.05	--	--	--	--	--	--	--	12,200	4,710	1,470	236	0	1,810	20,400
0	--	--	--	--	--	--	--	13,800	5,920	2,050	1,790	4	3,140	32,900

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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TABLE 17-14. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF MANGANESE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0.294 gm/sec
Residential coal burning	0.230 gm/sec
Residential oil burning	0.064 gm/sec
Nationwide nonheating stationary emissions (E_N)	19.211 gm/sec
Chemical applications	9.274 gm/sec
Battery production	3.974 gm/sec
Welding rod manufacturing	0.691 gm/sec
Industrial boiler coal combustion	5.069 gm/sec
Industrial boiler oil combustion	0.203 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 17-15. MANGANESE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.100000	446952	47097.2	.6	99.4	0.	100.0	0.	0.
.050000	505140	52100.4	.7	99.3	0.	100.0	0.	0.
.025000	9149730	405785.5	1.8	98.2	0.	100.0	0.	0.
.010000	37272291	839199.2	1.6	98.4	0.	100.0	0.	0.
.005000	92073728	1211820.7	1.6	98.4	0.	97.5	1.1	1.4
.002500	138413291	1387299.2	1.6	98.4	0.	94.5	2.4	3.1
0.	158679135	1421708.9	1.6	98.4	0.	92.9	2.6	4.5

TABLE 17-16. EXPOSURE AND DOSAGE SUMMARY OF MANGANESE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$) • persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
10	0	13,000	0	13,000	0	174,000	0	174,000
5	0	119,000	0	119,000	0	898,000	0	898,000
2.5	0	587,000	0	587,000	0	2,430,000	0	2,430,000
1	0	2,140,000	0	2,140,000	0	4,730,000	0	4,730,000
0.5	0	6,150,000	0	6,150,000	0	7,520,000	0	7,520,000
0.25	0	--	0	0	0	10,600,000	0	10,600,000
0.1	0	--	446,952	0	0	16,100,000	47,097	16,147,097
0.05	0	--	505,140	0	0	20,400,000	52,100	20,452,100
0.025	0	--	9,149,730	0	0	--	405,785	--
0.01	0	--	37,272,291	0	0	--	839,199	--
0.005	0	--	92,073,728	0	0	--	1,211,820	--
0.0025	0	--	138,413,291	0	0	--	1,387,299	--
0	0	--	158,679,135	0	0	32,900,000	1,421,708	34,321,708

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-18 ----- 1,1,1-Trichloroethane (Methyl Chloroform)

METHYL CHLOROFORM (1,1,1-TRICHLOROETHANE) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 71-55-6

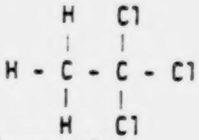
Synonyms: Alpha-Trichloroethane; Methyl Chloroform; Chlorothene; Aerothene TT, Dowclene WR; Chlorten; Trithane

Chemical Formula

Molecular Weight: 133.4

Molecular Formula: $CH_3\ CCl_3$

Molecular Structure:



$$\begin{array}{ccccccc} & & H & & Cl & & \\ & & | & & | & & \\ H & - & C & - & C & - & Cl \\ & & | & & | & & \\ & & H & & Cl & & \end{array}$$

Chemical and Physical Properties

Physical State at STP: Liquid-clear, nonflammable

Boiling Point: 74.1°C

Melting Point: 30.41°C

Density: 1.34 at 20°C/4°C

Vapor Pressure: 130 mm at 25°C

Vapor Density: 4.55

Solubility: soluble (1.3 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.32

Atmospheric Reactivity

Transformation Products: CO, HCl, HCOH, $COCl_2$, CH_3COCL, $CH_2ClCOCl$

$$\begin{array}{l}\text{Reactivity Toward OH}\cdot:\\ \text{Reactivity Toward } O_3:\end{array}\left\{\begin{array}{l}\text{inert to atmospheric}\\ \text{oxidation, t 1/2 > 5 yr.}\end{array}\right.$$

Reactivity Toward Photolysis: none

Major Atmospheric Precursors: N/A

Formation Reactivity: N/A

I. SOURCES

1,1,1 trichloroethane (methyl chloroform) is currently produced in the United States by two different processes.[1,2] The predominant method involves the use of vinyl chloride as a raw material. Vinyl chloride, produced from ethylene dichloride, is hydrochlorinated with hydrogen chloride to form 1,1-dichloroethane, which is then thermally chlorinated to produce 1,1,1 trichloroethane.

The alternate process, used only by Vulcan, uses ethane and chlorine as raw materials. 1,1,1 trichloroethane is produced by the continuous noncatalytic chlorination of ethane. Other chlorinated hydrocarbon co-products, such as ethyl chloride, vinyl chloride, etc., which are formed in this reaction in significant quantities, are recycled unless individual separation is required.

Only three companies at four locations currently produce 1,1,1 trichloroethane in the United States. The plant locations and the 1978 capacity and estimated production level for each plant are shown in Table 18-1.[1,2,3] An estimated 620 million lb of 1,1,1-trichloroethane was produced in 1978.

1,1,1 trichloroethane has many diverse end-uses. The largest end-use of 1,1,1 trichloroethane is in metal degreasing and cleaning operations. This end-use consumed an estimated 63% of production in 1978 amounting to 390 million lb. Of this total, 193 million lb was used in degreasers and 197 million lb was used in cold cleaners.

Most of the other applications of 1,1,1 trichloroethane are small and minor in importance when compared to degreasing use. Aerosol formulations consumed an estimated 30 million lb (5%) in 1978. An undisclosed use of 1,1,1 trichloroethane as a chemical intermediate has been reported to consume an estimated 15 million lb. Other applications of 1,1,1-trichloroethane include its use as a formulation and vehicle solvent in a wide variety of consumer products such as adhesives, nonflammable paints, urethane coatings, and other types of sealants. It is also used as an extraction solvent in nonfood and drug formulations, as a fabric and drain cleaner, and as a lubricant and coolant in cutting oils. Total consumption for this broad category is estimated to have been 135 million lb (22%) in 1978. Exports of 1,1,1-trichloroethane are estimated to have been 50 million lb (8%) in 1978. End-uses are summarized in Table 18-2.[1,2]

Table 18-1. Production of 1,1,1-Trichloroethane[a]

Source	Location	1978 Estimated Production ($\bar{M}$ lb)	1978 Estimated Capacity ($\bar{M}$ lb)	Geographic Coordinates
Dow Chemical	Freeport, TX	266	500	28 59 15 N. latitude 95 24 45 W. longitude
Dow Chemical	Plaquemine, LA	160	300	30 19 00 N. latitude 91 15 32 W. longitude
PPG Industries	Lake Charles, LA	160	300	30 13 14 N. latitude 93 16 54 W. longitude
Vulcan Chemical Co.	Geismar, LA	34	65	30 10 00 N. latitude 90 59 00 W. longitude
Total		620	1165	

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[a] See refs. 1—3.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production to total U.S. capacity as compared to individual plant capacity.

Table 18-2. 1978 1,1,1-Trichloroethane Consumption by End-Use*

End-Use	% of Total Consumption	End-Use Consumption ($\bar{M}$ lb)
Metal cleaning, degreasing	63	390
Chemical intermediate	2	15
Aerosols	5	30
Vehicle solvent, cleaner, misc.	22	135
Export	8	50
Total	100	620

*See refs. 1,2.

II. EMISSION ESTIMATES

A. PRODUCTION

Estimated production losses are shown in Table 18-3 for each of the four producing locations.[4,5,6] Total emissions of 1,1,1 trichloroethane from production facilities are estimated to have been 1,318,200 lb in 1978. Process emissions originate primarily through the condenser vents from the distillation columns. Other associated emission components include ethyl chloride, vinyl chloride, vinylidene chloride, hydrogen chloride, and 1,1-dichloroethane. Storage emissions, which account for over half of the estimated production losses, represent the total losses from both working and final product storage tanks and from loading and handling. Fugitive emissions are those emissions which result from plant equipment leaks.

Vent stack data are shown in Table 18-4. Normally three process and seven storage tank vents are involved in the production and storage emissions. Usually 1,1,1 trichloroethane production facilities are "open air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed.

B. USES

For the purpose of this report, emissions resulting from the export of 1,1,1 trichloroethane are assumed to be negligible. The total amount of 1,1,1-trichloroethane used in aerosol formulations (30 million lb) and miscellaneous solvent and cleaning applications (135 million lb) is eventually released to the atmosphere. Statistical data on individual solvent use by specific classification or category are not available and are usually estimated as a group by difference. Therefore, no point sources or model sources other than the use in aerosols and chemical intermediates were identified. The losses from aerosol and miscellaneous solvent applications are probably distributed geographically in proportion to the population of the United States. Emissions resulting from use as a chemical intermediate (60,000 lb) were estimated by using the 1,1,1-trichloroethane production emission factor. A specific location for chemical intermediate use of 1,1,1-trichloroethane could not be identified.

1,1,1-trichloroethane vapor degreasing emissions are estimated to have been 371.2 million lb in 1978 or 95.2% of the total quantity of 1,1,1-trichloroethane consumed for that end-use.[7,8] An estimated 9.5% of the 1,1,1-trichloroethane

Table 18-3 1978 1,1,1-Trichloroethane Production Emissions [a]

Company	Location	1978 Production ($lb \times 10^6$)	Process Emissions ($lb \times 10^4$)	Storage Emissions ($lb \times 10^4$)	Fugitive Emissions ($lb \times 10^4$)	Total Emissions ($lb \times 10^4$)[b]	Total Emissions (g/sec)[c]
Dow[d]	Freeport, TX	266	9.36	29.53	13.02	51.91	7.47
Dow [d]	Plaquemine, LA	160	0.0	1.74	.76	2.50	.36
PPG	Lake Charles, LA	160	11.50	36.32	16.00	63.84	9.19
Vulcan	Geismar, LA	34	2.46	7.72	3.4	13.57	1.95
Total		620	23.32	75.31	33.18	131.82	18.97

[a] See refs. 4--6.

[b] Emission factor for 1,1,1-trichloroethane (lb trichloroethane lost/lb trichloroethane produced)

Process	0.00072	B - (derived from state air emission files)
Storage	0.00227	B - (derived from state air emission files)
Fugitive	0.00100	D - (derived from engineering estimate)
Total	0.00399	

Fugitive emissions are released over a 300 x 300 ft area.

[c] 8760 operating hours per year, i.e., 24 hr/day, 7 days/ wk, 52 wk/yr.

[d] See ref. 9

Table 18-4. 1,1,1-Trichloroethane Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[a]					
Process vents	3	50	0.17	100	5.0
Storage vents	7	15—20	0.66	70	
Use[b]					
Cold cleaner	1	15	0.5	70	0.6
Open top degreaser	1	15	0.5	130	

[a] Building cross-section - 5 m^2.

[b] Building cross-section - 50 m^2.

used in cold cleaners is encapsulated or burned and is not released to the atmosphere.[8] The estimated emissions from degreasing operations are 178.5 million lb from cold cleaners and 192.7 million lb from degreasers. The average emission rates per unit and the total number of units in operation nationally are shown in Table 18-5. The estimated number of degreasers using 1,1,1-trichloroethane in 1978 by geographic region is shown in Table 18-6.[8]

Total nationwide emissions of 1,1,1-trichloroethane in 1978 from all sources are estimated to have been 537,580,000 lb. A tabulation of the losses is shown in Table 18-7.

Table 18-5. 1,1,1-Trichloroethane Emissions from Solvent Degreasers

Type Degreaser	Estimated National Emission ($\bar{M}$ lb/yr)	Estimated Number of Units in Service	Average Emission Rate per Unit[a] (lb/yr)	Average Emission Rate per Unit[a] (g/sec)[b]
Cold Cleaners	178.5	270,045	661	0.04
Open top vapor degreasers	128.5	6,425	20,000	1.13
Conveyorized degreasers	64.2	1,080	59,500	3.35
Total	371.2	277,550		
Weighted Average			1,337	0.07

[a] See ref. 7.

[b] The number of annual operating hours was assumed to be 2250.

Table 18-6. Estimated Number of Degreasers Using 1,1,1-Trichloroethane in 1978 by Geographic Location*

Degreaser Type	North East	Mid Atlantic	East North-Central	West North-Central	South Atlantic	East South-Central	West South-Central	Mountain	Pacific	TOTAL
Cold cleaners	16,234	42,101	71,498	23,675	32,577	15,974	26,216	9,799	31,971	270,045
Open top vapor degreasers	589	1,217	1,832	475	490	279	418	183	942	6,425
Closed con-veyorized degreasers	99	214	355	70	74	46	60	18	145	1,080

*See ref. 8.

Table 18-7. 1978 Estimated 1,1,1-Trichloroethane Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	1.32
Metal cleaning (degreasing) - use	371.2
Solvent, cleaner, misc - use	135.0
Aerosols - use	30.0
Chemical intermediate - use	0.06
Export	0
Total	537.58

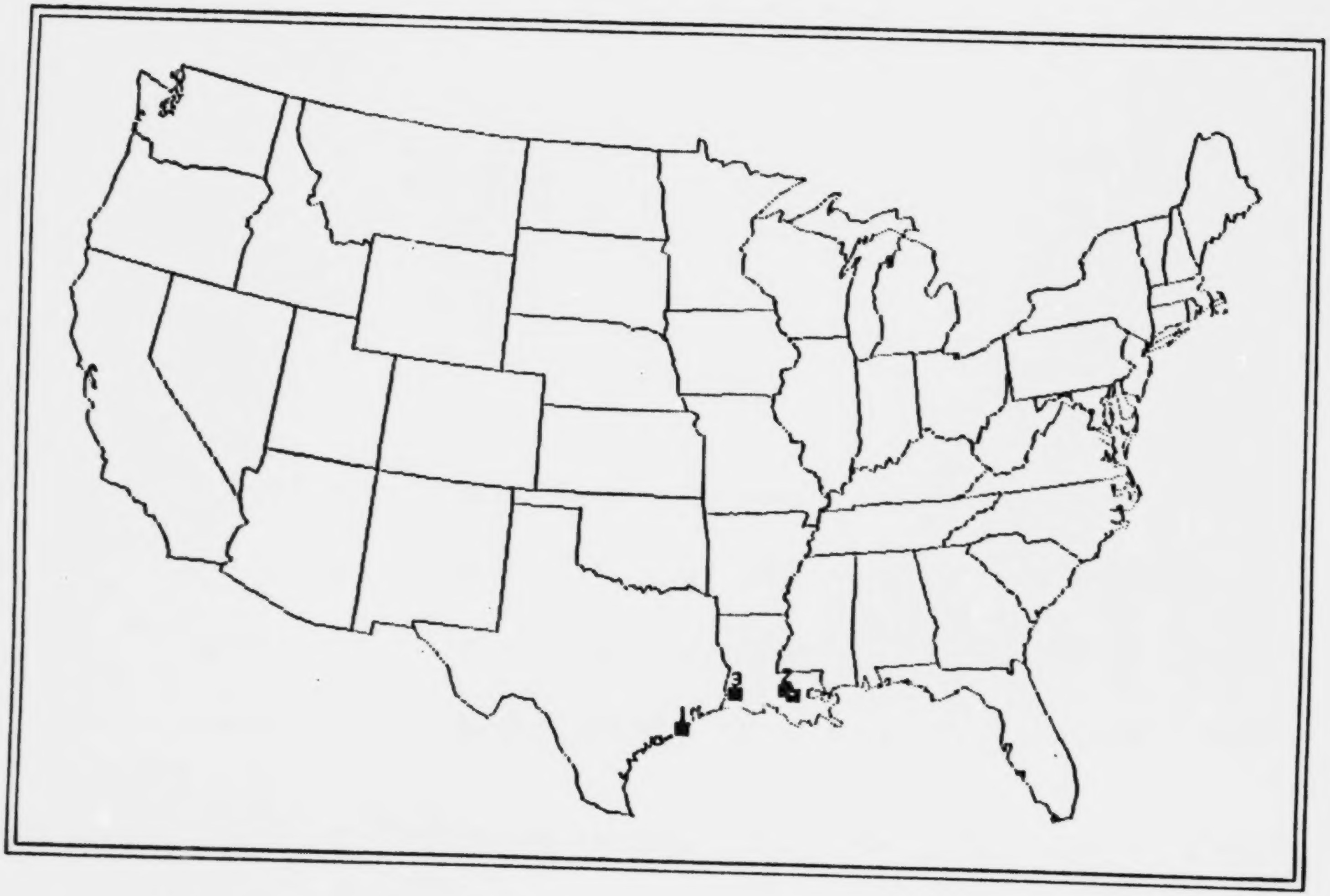

FIGURE 18-1. SPECIFIC POINT SOURCES OF 1,1,1-TRICHLOROETHANE EMISSIONS

Table 18-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF 1,1,1-TRICHLOROETHANE

					Star	Plant	Source	EMISSIONS (GM/SEC)		
No.	Company	Site	Latitude	Longitude	Station	Type	Type	Process	Storage	Fugitive
1	Dow	Freeport, TX	28 59 30	095 23 35	12923	1	1	1.346082	4.248699	1.873129
2.	Dow	Plaquemine, LA.	30 19 00	091 15 00	13970	1	1	0.	0.249718	2.304002
3	PPG	Lake Charles, LA	30 13 14	093 16 54	03937	1	1	1.656012	5.230022	2.304002
4	Vulcan	Geismar, LA	30 10 00	090 59 00	12958	1	1	.354243	1.117431	.489599

TABLE 18-9. EXPOSURE AND DOSAGE OF 1,1,1-TRICHLOROETHANE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed* (persons)	Dosage [(ug/m^3) . persons]
50	2	137
25	10	387
10	85	1,380
5	427	3,420
2.5	1,982	8,430
1	9,036	18,700
0.5	32,600	34,600
0.25	73,844	48,800
0.1	189,148	65,700
0.00105*	461,832	71,300

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 18-10. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF 1,1,1-TRICHLOROETHANE

Region	Cold Cleaning		Open Top Vapor Degreasing (OTVD)		Conveyorized Vapor Degreasing (CVD)	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00952	16,234	0.288	589	0.857	99
Middle Atlantic	0.00952	42,101	0.288	1,217	0.857	214
East North Central	0.00952	71,498	0.288	1,832	0.857	355
West North Central	0.00952	23,675	0.288	475	0.857	70
South Atlantic	0.00952	32,577	0.288	490	0.857	74
East South Central	0.00952	15,974	0.288	279	0.857	46
West South Central	0.00952	26,216	0.288	418	0.857	60
Mountain	0.00952	9,799	0.288	183	0.857	18
Pacific	0.00952	31,971	0.288	942	0.857	145

TABLE 18-11. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF 1,1,1-TRICHLOROETHANE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)				Dosage [$10^6(\mu g/m^3) \cdot$ persons]			
	Cold Degreasing	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total	Cold Degreasing	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total
25	0	0	12	12	0	0	0.4	0.4
10	0	60	155	215	0	0.7	2.4	3
5	0	379	472	851	0	2.7	4.6	7
2.5	0	1,550	1,030	2,580	0	6.6	6.5	13
1	--	--	--	--	0	11.8	10.5	22
0.5	--	--	--	--	0	244	15	32
0.25	--	--	--	--	1.3	24.4	19	45
0.1	--	--	--	--	7.2	36	26	69
0.05	--	--	--	--	12.9	47	32	92
0.025	--	--	--	--	19.2	55	37	111
0.01	--	--	--	--	29.4	71	47	147
0.005	--	--	--	--	42.2	84	52	178
0.0025	--	--	--	--	54.9	97	53	204
0.001	--	--	--	--	71.3	105	53	229
0	--	--	--	--	146	105	53	304

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 18-12. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF 1,1,1-TRICHLOROETHANE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	2376 gm/sec
Aerosol formation	432 gm/sec
Miscellaneous	1944 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 18-13. 1,1,1-TRICHLOROETHANE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
10.000000	505140	6400236.4	0.	100.0	0.	100.0	0.	0.
5.000000	505140	6400236.4	0.	100.0	0.	100.0	0.	0.
2.500000	11147543	54715139.6	0.	100.0	0.	100.0	0.	0.
1.000000	43314528	108733700.5	0.	100.0	0.	99.2	.2	.6
.500000	108928270	156869401.7	0.	100.0	0.	96.6	1.6	1.8
.250000	145742124	170896866.9	0.	100.0	0.	93.8	2.5	3.7
0.	158679135	173047296.4	0.	100.0	0.	92.9	2.6	4.5

TABLE 18-14. EXPOSURE AND DOSAGE SUMMARY OF 1,1,1-TRICHLOROETHANE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) . persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
50	2	0	0	2	137	0	0	137
25	10	12,000	0	12,010	387	400,000	6,400,236	6,800,623
10	85	215,000	505,140	720,225	1,380	3,000,000	6,400,236	9,401,616
5	427	851,000	505,140	1,356,567	3,420	7,000,000	54,715,139	61,718,559
2.5	1,982	2,580,000	11,147,543	13,729,525	8,430	13,000,000	108,733,700	121,742,130
1	9,036	--	43,314,528	--	18,700	22,000,000	156,869,401	178,888,101
0.5	32,600	--	108,928,270	--	34,600	32,000,000	170,896,866	202,931,466
0.25	73,844	--	145,742,124	--	48,800	45,000,000	--	--
0.1	189,148	--	--	--	65,700	69,000,000	--	--
0.05	--	--	--	--	--	92,000,000	--	--
0.025	--	--	--	--	--	111,000,000	--	--
0.01	--	--	--	--	--	147,000,000	--	--
0.005	--	--	--	--	--	178,000,000	--	--
0.0025	--	--	--	--	--	204,000,000	--	--
0.001	--	--	--	--	--	229,000,000	--	--
0	461,832	--	158,679,135	--	71,300	304,000,000	173,047,000	477,118,300

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-19 ----- Methylene Chloride

METHYLENE CHLORIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-09-2

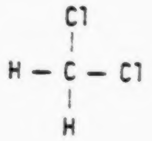
Synonyms: Methylene Chloride; Methylene Dichloride; Dichloromethane; Methylene Bichloride

Chemical Formula

Molecular Weight: 84.93

Molecular Formula: CH_2Cl_2

Molecular Structure:



$$\begin{array}{ccccc} & & Cl & & \\ & & | & & \\ H & - & C & - & Cl \\ & & | & & \\ & & H & & \end{array}$$

Chemical and Physical Properties

Physical State at STP: liquid -colorless, pleasant odor

Boiling Point: 40°C at 760 mm

Melting Point: 95.1°C

Density: 1.3266 at 20°C/4°C

Vapor Pressure: 435.8 mm at 25°C

Vapor Density: 2.93

Solubility: slightly soluble (13 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 1.25

Atmospheric Reactivity

Transformation Products: CO_2, HCl, CO, $COCl_2$

Reactivity Toward OH·: t 1/2 ~ 1 yr., < methane

Reactivity Toward O_3: No Reaction

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity: N/A

I. SOURCES

Four volatile organic compounds——methyl chloride, methylene chloride, chloroform, and carbon tetrachloride——comprise the group of chemicals commonly referred to as the chloromethanes. Emission losses for all except methyl chloride are assessed in this summary.

A. METHYLENE CHLORIDE

Methylene chloride (CH_2Cl_2) is a heavy volatile liquid at ambient conditions and is produced by the chlorination of either methyl chloride or methane.

The methane chlorination process yields methylene chloride as well as methyl chloride, chloroform, and carbon tetrachloride. The methyl chloride process involves the reaction of methanol and hydrogen chloride to yield methyl chloride which is subsequently reacted with chlorine to form methylene chloride and other chlorinated methanes.[1,2]

The latter process is used extensively by those producers who have large captive uses for methyl chloride such as in silicone or tetramethyl lead manufacture. Variations in the methane chlorination process conditions and in the amount of methyl chloride recycled can significantly change the various product yield ratios. This minimizes inventory problems that might be created by changing market demand. Capacities for each of the chloromethanes at any producing site are very flexible.[1,2]

In 1978 five domestic producers of methylene chloride were operating seven plants. The locations of the plants, the type of production process used, and the 1978 capacity and estimated production level for each plant are shown in Table 19-1.[3,4,5] An estimated 525 million lb of methylene chloride was produced in 1978.[3]

Methylene chloride has many diverse end-uses, the largest being in the formulation of industrial and household paint and varnish removers. An estimated 157.5 million lb representing 30% of the total methylene chloride production was consumed for this end-use in 1978.

Table 19-1. Production of Methylene Chloride[a]

Source	Location	1978 Estimated Production[b] (10^6 lb/yr)	Process[c]	1978 Estimated Capacity (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical Corp.	Moundsville, WV	31	A,B[d]	50	39 54 24/80 47 51
Diamond Shamrock	Belle, WV	63	A	100	38 14 09/81 32 38
Dow Chemical	Freeport, TX	125	B	200	28 59 15/95 24 45
	Plaquemine, LA	112	A	180	30 19 00/91 15 00
Stauffer	Louisville, KY	38	A	60	38 12 09/85 51 49
Vulcan Materials Co.	Geismar, LA	50	A	80	30 10 00/90 59 00
	Wichita, KS	106	A,B[e]	170	37 36 55/97 18 30
Total		525		840	

---

[a] See refs. 3—5.

[b] Distribution of the 525 million pounds per year for each producing location has been made as a direct ratio of total production/total capacity X individual plant capacity.

[c] (A) - Methanol hydrochlorination process or methyl chloride chlorination process.
(B) - Methane chlorination process.

[d] 5% methane chlorination 95% methyl chloride chlorination.

[e] 10% methane chlorination 90% methyl chloride chlorination.

The second largest end-use of methylene chloride is as a metal degreasing solvent. An estimated 115.5 million lb was consumed for this purpose with 88.5 million lb used in cold cleaners and 27.0 million lb used in degreasers. Exports consumed 110.25 million lb (21%) in 1978 representing the third largest end-use category. The use of methylene chloride as a vapor depressant in aerosols is estimated to have consumed 89.25 million lb in 1978.

Methylene chloride is also used as a chemical intermediate in the manufacture of various drugs, dyes, and perfumes and in the dewaxing of oils, as a decaffeinating agent for coffee, and as a foaming agent for flexible polyurethane foams. Total end-use for all of these applications is estimated to have been 26.25 million lb in 1978. An equivalent amount of methylene chloride (26.25 million lb) was consumed as a solvent in plastics processing. End uses are summarized in Table 19-2.[3,4]

II. EMISSION ESTIMATES

Estimated emission losses from the production of methylene chloride for each producing location are shown in Table 19-3. Total emissions of methylene chloride, chloroform, and carbon tetrachloride from production facilities are estimated to have been 645,914 lb, 351,280 lb, and 4,141,360 lb respectively in 1978. These estimates are based on the emission factors generated for each of the four processes used in the industry as shown in Table 19-4.[1,2,10] Other associated emission components include methyl chloride and hydrogen chloride from the methyl chloride and methane chlorination processes and perchloroethylene, ethylene dichloride, and tetrachloroethane from the carbon disulfide/hydrocarbon chlorinolysis processes.

Process emissions originate primarily from the inert gas purge vent from the methyl chloride or primary product recovery condenser. They also originate from the methylene chloride, chloroform, and carbon tetrachloride distillation columns. Storage emissions represent the total losses from crude and final product storage tanks as well as loading and handling losses. Fugitive emissions are those emissions which occur when leaks develop in valves, pumps, seals, or other equipment. Corrosion caused by the hydrogen chloride or chlorine used in the process can result in more frequent leakage, which increases the amount of fugitive emissions compared to other processes.

Table 19-2. 1978 Methylene Chloride Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption ($\bar{M}$ lb)
Paint and varnish remover	30	157.5
Metal degreasing	22	115.5
Aerosols	17	89.25
Plastics processing	5	26.25
Export	21	110.25
Miscellaneous	5	26.25
Total	100	525

*See refs. 3 and 4.

Table 19-3. 1978 Methylene Chloride Production Emissions

Company	Location	Process Vent Emissions		Storage Vent Emissions		Fugitive Emissions		Total emissions[a]	
		(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]	(lb/yr)	(g/sec)[b]
Allied Chemical	Moundsville, WV	980	0.014	74,030	1.066	14,430	0.208	89,440	1.288
Diamond Shamrock	Belle, WV	164	0.002	15,498	0.223	2,980	0.043	18,642	0.268
Dow Chemical[c]	Freeport, TX	16,353	0.235	119,566	1.720	37,780	0.543	173,699	2,498
	Plaquemine, LA	234	0.003	22,178	0.319	4,268	0.061	26,680	0,383
Stauffer	Louisville, KY	990	0.014	93,480	1.346	17,970	0.259	112,440	1.619
Vulcan[d]	Geismar, LA	1,300	0.019	123,000	1.771	23,650	0.340	147,950	2.130
	Wichita, KA	3,960	0.057	24,553	0.353	48,550	0.699	77,063	1.109
Total		23,981		472,305		149,628		645,914	

[a] Derived from the emission factors shown in Table 10.

[b] Based on 8760 hr/yr operation.

[c] See ref. 15

[d] See ref. 16

Table 19-4. Chloromethane Production Emission Factors

Process Designation		Emission Factors (lb of product lost/lb of product produced) Methylene Chloride	Chloroform	Carbon Tetrachloride
(A) Methyl chloride chlorination[a]	Process	0.000026	0.000008	
	Storage	0.002460	0.000975	0.000076
	Fugitive	0.000473	0.000247	0.000020
Total		0.002959	0.001230	0.000096
(B) Methane chlorination[b]	Process	0.00014	0.000004	0.000005
	Storage	0.00102	0.000289	0.000127
	Fugitive	0.00032	0.000180	0.000072
Total		0.00148	0.000473	0.000204
(C) Chlorinolysis[c]	Process			0.000008
	Storage			0.001670
	Fugitive			0.000490
Total				0.002168
(D) Carbon disulfide[c]	Process			0.0100
	Storage			0.0034
	Fugitive			0.0006
Total				0.0140

[a] A—derived from site visit. See ref. 2.

[b] A—derived from site visit. See ref. 1.

[c] A—derived from site visit. See ref. 10.

Chloromethane production end-use vent stack data are shown in Table 19-5.[1,2,10] Typically there are three process vents and ten storage tanks which emit chloromethanes in the methyl chloride chlorination process. The methane chlorination process generally has just two process vents and ten storage tanks. The carbon disulfide and other chlorination processes used to produce carbon tetrachloride normally have two process vents and seven storage tanks. All chloromethane production facilities are open air structures without walls and solid floors (i.e., steel grating) and with only the control room area enclosed.

USES

The total quantity of methylene chloride used in paint and varnish removers (157.5 million lb), aerosol formulations (89.25 million lb), plastics processing (26.25 million lb), and miscellaneous applications (26.25 million lb) is eventually released to the atmosphere. These losses are distributed geographically approximately in proportion to the industrialized population in the United States.

Methylene chloride emissions from degreasing operations are estimated to have been 107.1 million lb in 1978. An estimated 8.4 million lb of methylene chloride from cold cleaners was encapsulated (landfilled) or burned.[11] The emissions from degreasing operations are split between cold cleaners (75%) and degreasers (25%). The emissions from degreasing operations, the average emission rates per unit, and the total number of units in operation nationally are shown in Table 19-6.[11] The estimated number of degreasers using methylene chloride in 1978 by geographic region is shown in Table 19-7.[12]

Total nationwide emissions of methylene chloride in 1978 from all sources are estimated to have been 407,000,000 lb. A tabulation of the losses is shown in Table 19-8.

Table 19-5. Chloromethane Vent Parameters[a]

Source	Number of Vents	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Production[b]					
Methyl chloride chlorination					
Process	3	35	0.08	95	5.0
Storage	10	20	0.17	80	
Methane chlorination					
Process	2	35	0.08	100	270
Storage	10	20	0.17	80	
Carbon disulfide and other chlorination processes					
Process	2	45	0.17	100	9.0
Storage	7	20	0.17	80	
Methylene chloride end-use[c]					
Cold cleaner	1	15	0.5	70	0.6
Vapor degreaser	1	15	0.5	150	
Fluorocarbons 11/12[d]					
Process	2	30	0.33	90	
Storage	4	20	0.17	80	
Fluorocarbon 22[d]					
Process[e]	0	0	0	0	0
Storage	2	20	0.17	80	

[a] See refs. 1, 2, 10, and 14.

[b] Building cross-section - 5 m^2

[c] Building cross-section - 50 m^2

[d] Building cross-section - 20 m^2

[e] There are no process vent losses of chloroform from f-22 manufacture.

Table 19-6. Methylene Chloride Emissions from Solvent Degreasers[a]

Type	Estimated National Emission (M̄ lb/yr)	Estimated Number of Units in Service	Average Emission Rate per Unit (lb/yr)	Average Emission Rate per Unit (g/sec)[b]
Cold cleaners	80.1	121,180	661	0.04
Open-top vapor degreasers	18.0	900	20,000	1.13
Conveyorized degreasers	9.0	151	59,500	3.35
Total	107.1	122,231		
Weighted average			876	0.05

[a] See ref. 11.

[b] The number of annual operating hours was assumed to be 2250.

Table 19-7. Estimated Number of Degreasers Using Methylene Chloride in 1978 by Geographic Location*

Degreaser Type	North East	Mid Atlantic	East North-Central	West North-Central	South Atlantic	East South-Central	West South-Central	Mountain	Pacific	Total
Cold cleaners	7,284	18,892	32,084	10,624	14,620	7,168	11,764	4,397	14,347	121,180
Open top vapor degreasers	82	170	257	66	69	39	59	26	132	900
Closed conveyorized degreasers	14	30	50	10	10	6	8	3	20	151

*See ref. 12.

Table 19-8. 1978 Methylene Chloride Nationwide Emission Losses

Source	Estimated National Emission ($\bar{M}$ lb/yr)
Production	0.65
Paint and varnish remover	157.5
Metal degreasing	107.1
Aerosols	89.25
Plastics processing	26.25
Miscellaneous	26.25
Export	0
Total	407.00

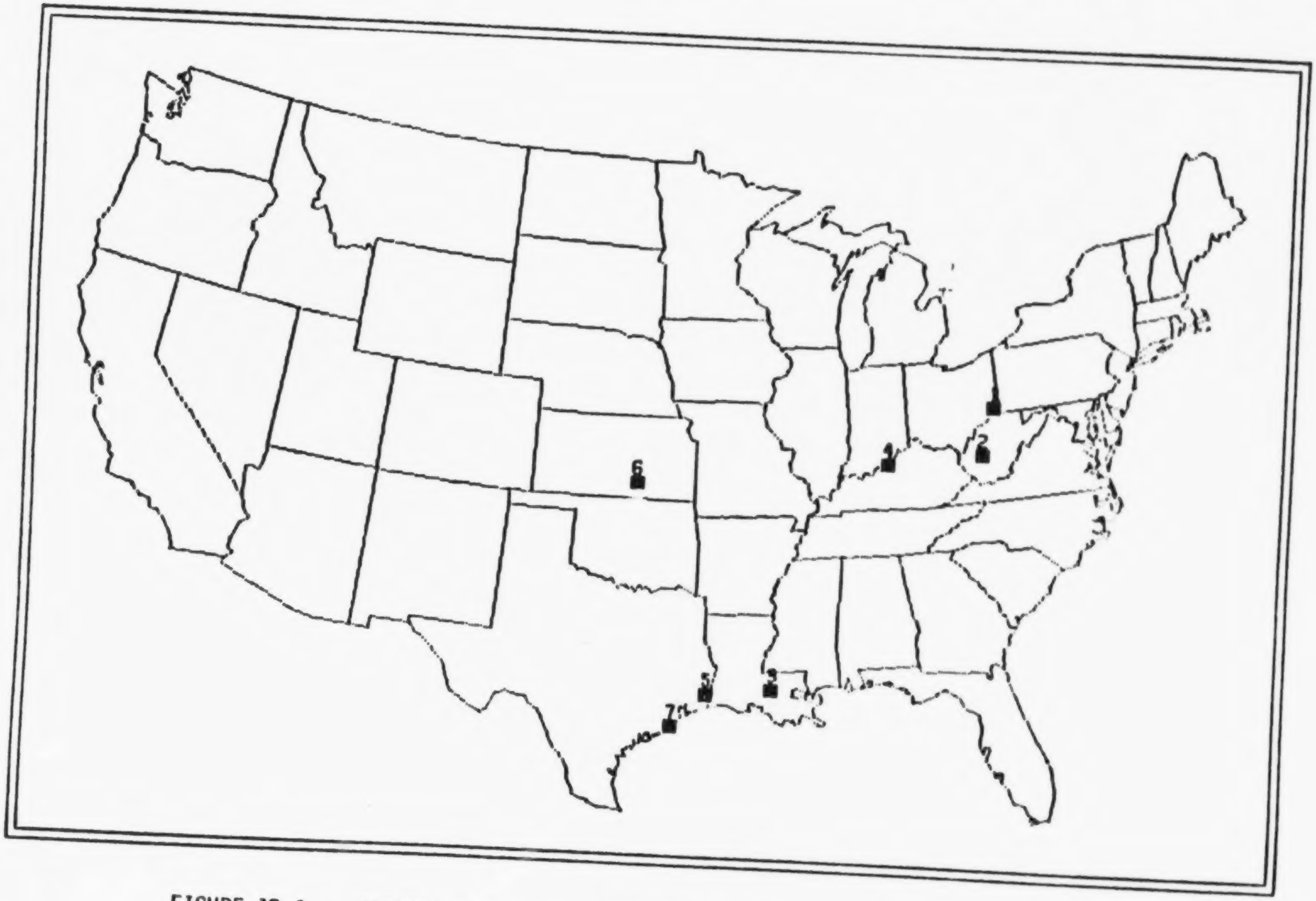


FIGURE 19-1. SPECIFIC POINT SOURCES OF METHYLENE CHLORIDE EMISSIONS

Table 19-10. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF METHYLENE CHLORIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	1	1	.014112	1.022831	.207791
2	DIAMOND SHAMROC	BELLE, WV	38 14 09	081 32 38	13866	1	1	.002347	.222920	.042872
3	DOW CHEMICAL	PLAQUEMINE, LA	30 19 00	091 15 00	13970	1	1	.003372	.319286	.061393
4	STAUFFER	LOUISVILLE, KY	38 12 09	085 51 49	93820	1	1	.014256	1.346112	.258768
5	VULCAN	GEISMAR, LA	30 10 00	093 59 00	12958	1	1	.018720	1.771214	.340563
6	VULCAN	WICHITA, KA	37 36 55	097 18 30	13968	1	1	.056957	.353152	.698313
7	DOW CHEMICAL	FREEPORT, TX	28 59 30	095 23 35	12923	2	2	.235214	1.719780	.543411

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* Plant Types:

Type 1: Plant produces methylene chloride by using methyl chloride chlorination process

Type 2: Plant produces methylene chloride by using methane chlorination process

+ Source Types:

Type 1: Methyl chloride chlorination process

Type 2: Methane chlorination process

TABLE 19-11. EXPOSURE AND DOSAGE OF METHYLENE CHLORIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (μg/m^3)	Population Exposed (persons)	Dosage [(μg/m^3) • persons]
50	12	781
25	52	2,090
10	189	4,110
5	448	5,900
2.5	5,768	23,300
1	16,046	35,600
0.5	30,805	47,200
0.25	63,272	58,000
0.1	165,543	73,500
0.05	387,750	88,400
0.004*	1,694,524	116,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 19-12. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF METHYLENE CHLORIDE

Region	Cold Cleaning		Open Top Vapor Degreasing (OTVD)		Conveyorized Vapor Degreasing (CVD)	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00952	7,284	0.288	82	0.857	14
Middle Atlantic	0.00952	18,892	0.288	170	0.857	30
East North Central	0.00952	32,084	0.288	257	0.857	50
West North Central	0.00952	10,624	0.288	66	0.857	10
South Atlantic	0.00952	14,620	0.288	69	0.857	10
East South Central	0.00952	7,168	0.288	39	0.857	6
West South Central	0.00952	11,764	0.288	59	0.857	8
Mountain	0.00952	4,397	0.288	26	0.857	3
Pacific	0.00952	14,347	0.288	132	0.857	20

TABLE 19-13. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF METHYLENE CHLORIDE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)				Dosage [$10^6(\mu g/m^3) \cdot$ persons]			
	Cold Cleaning	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total	Cold Cleaning	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total
25	0	0	1.7	1.7	0	0	0.056	0.056
10	0	8.3	21.6	30	0	0.10	0.34	0.44
5	0	53	65.8	119	0	0.38	0.64	1.02
2.5	0	217	143	360	0	0.93	0.91	1.84
1	0	682	503	1,180	0	1.65	1.46	3.12
0.5	0	1,790	1,420	3,210	0	2.42	2.09	4.5
0.25	--	--	--	--	0.58	3.41	2.68	6.7
0.1	--	--	--	--	3.22	5.00	3.61	11.8
0.05	--	--	--	--	5.78	6.59	4.42	16.8
0.025	--	--	--	--	8.60	7.65	5.21	21.5
0.01	--	--	--	--	13.2	9.93	6.48	29.6
0.005	--	--	--	--	19.0	11.8	7.18	37.9
0.0025	--	--	--	--	26.6	13.5	7.38	45.5
0.001	--	--	--	--	32.0	14.6	7.40	54.0
0	--	--	--	--	65.5	14.7	7.40	87.6

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 19-14. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF METHYLENE CHLORIDE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	4309 gm/sec
Paint and varnish removing	2268 gm/sec
Aerosol formulation	1285 gm/sec
Plastic processing	378 gm/sec
Miscellaneous	378 gm/sec
Nationwide mobile source emissions	0

TABLE 19-15. METHYLENE CHLORIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
10.000000	505140	11607162.7	0.	100.0	0.	100.0	0.	0.
5.000000	9149730	89340851.2	0.	100.0	0.	100.0	0.	0.
2.500000	33072205	175526212.2	0.	100.0	0.	100.0	0.	0.
1.000000	101318744	277269308.4	0.	100.0	0.	97.1	1.4	1.5
.500000	142826781	308556733.5	0.	100.0	0.	94.1	2.5	3.4
0.	158679135	313830303.2	0.	100.0	0.	92.9	2.6	4.5

TABLE 19-16. EXPOSURE AND DOSAGE SUMMARY OF METHYLENE CHLORIDE

	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
Concentration Level (ug/m^3)	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
50	12	0	0	12	781	0	0	781
25	52	1,700	0	1,752	2,090	56,000	0	58,090
10	189	30,000	505,140	535,329	4,110	440,000	11,607,163	12,051,273
5	448	119,000	9,149,730	9,269,178	5,900	1,020,000	89,340,851	90,366,751
2.5	5,768	360,000	33,072,205	33,437,973	23,300	1,040,000	175,526,212	--
1	16,046	1,180,000	101,318,744	--	35,600	3,120,000	277,269,308	--
0.5	30,885	3,210,000	142,826,781	--	47,200	4,500,000	308,556,733	--
0.25	63,272	--	--	--	58,000	6,700,000	--	--
0.1	165,543	--	--	--	73,500	11,800,000	--	--
0.05	387,750	--	--	--	88,400	16,800,000	--	--
0.025	--	--	--	--	108,000	21,500,000	--	--
0.01	--	--	--	--	--	29,600,000	--	--
0.005	--	--	--	--	--	37,900,000	--	--
0.0025	--	--	--	--	--	45,500,000	--	--
0.001	--	--	--	--	--	54,000,000	--	--
0	1,694,524	--	158,679,135	--	116,000	87,600,000	313,830,000	401,546,000

NOTE: The use of - as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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16. Vulcan Materials Company, (Thomas A. Robinson) Personal Communication in response to publication of the first draft of this report (October 1980).

APPENDIX A-20 ----- Nitrosomorpholine

For an explanation of the assumptions used to make these exposure estimates, please refer to the discussion beginning on Page 57 of this report

MORPHOLINE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 110-91-8

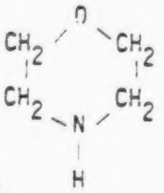
Synonyms: Diethylenimide Oxide; Tetrahydro-1,4-Isoxazine; Tetrahydro-2H,4 Oxazine; Diethylene Oximide; Diethylene Imidoxide

Chemical Formula

Molecular Weight: 87.12

Molecular Formula: C_4H_9NO

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid-mobile, hygroscopic, amine odor

Boiling Point: 128.3°C

Melting Point: -4.75°C

Density: 1.00 at 20°C/4°C

Vapor Pressure: 10 mm at 23°C

Vapor Density: 3.00

Solubility: Infinite (H_2O)

Log Partition Coefficient (Octanol/H_2O): -1.08

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Morpholine is produced by the dehydration of diethanolamine. The diethanolamine is produced by reacting ethylene oxide with ammonia. Morpholine processes are integrated into the ethanolamine facility.

Currently, Jefferson Chemical is the only company in the United States that produces morpholine (two locations as shown in Table 20-1).[1] In 1978, an estimated 25 million lb of morpholine was produced.

B. USES

Morpholine has many diverse end-uses. The largest end-use of morpholine is as an intermediate in the production of rubber processing chemicals, particularly accelerators. An estimated 35% of morpholine production (8.8 million lb) was consumed for this end-use. The second largest application for morpholine is as a corrosion inhibitor in steam condensate systems. An estimated 7.5 million lb (30%) was consumed for this end-use.

Most of the other applications of morpholine are small in quantity. Approximately 2.5 million lb of morpholine is used as an intermediate to produce optical brighteners for the soap and detergent industry. An equivalent amount (2.5 million lb) was used in formulating polishes and waxes. Miscellaneous applications consuming 2 million lb include the pharmaceutical industry, deodorants, shampoos, cosmetics, and disinfectants. An estimated 1.7 million lb was exported. End-uses of morpholine are summarized in Table 20-2.[1 2]

II. EMISSION ESTIMATES

A. PRODUCTION

Morpholine emissions from production sites are presented in Table 20-3. Total estimated emissions from these sites were 13,700 lb for 1978. The emission factors used to develop process vent, storage, and fugitive emission estimates (shown in Table 20-3) were assumed to be similar to ethylene oxide in the absence

Table 20-1. Morpholine Producers

Company	Location	1978 Capacity[b] (10^6 lb/yr)	1978 Production[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Jefferson	Port Neches, TX	14	12.5	29 57 45/93 56 00
	Conroe, TX	14	12.5	30 18 50/95 23 06
Total		28	25.0	

[a] See refs. 1 and 2.

[b] Capacity and production were distributed evenly over both sites since individual capacities were not available.

Table 20-2. Morpholine End-Use Distribution 1978*

Use	Usage (10^6 lb/yr)	Usage (%)
Rubber chemicals	8.8	35
Corrosion inhibitors	7.5	30
Optical brighteners	2.5	10
Polishes and waxes	2.5	10
Miscellaneous	2.0	8
Exports	1.7	7
Total	25.0	100

*See refs. 1 and 2.

Table 20-3. 1978 Morpholine Production Emissions

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a]	
					(lb/yr)	(g/sec)[b]
Jefferson	Port Neches, TX	6,560	260	25	6,850	0.099
	Conroe, TX	6,560	260	25	6,850	0.099
Total		13,125	525	50	13,700	

[a] Based on the following emission factor (lb lost per lb produced)

Process	0.000525	A - Derived from site visit data
Storage	0.000021	A - Derived from site visit data
Fugitive	0.000002	A - Derived from site visit data
Total	0.000548	

[b] Based on 8760 hr/yr operation.

of data on morpholine emissions. Process vent emissions would originate from the stripping, evaporating, drying, and fractionating operations,[3] while storage emissions represent losses from both working and final product storage loading and unloading. Fugitive emissons are those resulting from leaks from plant equipment. Emission estimates are based on a plant operating schedule of 24 hr/day, 7 days/week, 52 weeks/yr.

Other associated emission components would include diethanolamine and ammonia. Vent parameter data are shown in Table 20-4.

B. USES

For the purpose of this report, emissions resulting from the export of morpholine are assumed to be negligible.

The total amount of morpholine used as a corrosion inhibitor in boiler systems (7.5 million lb) and in polish and wax formulating (2.5 million lb) is eventually released to the atmosphere. The losses from these two applications and from morpholine's use as a chemical intermediate in miscellaneous applications (2000 lb) are probably distributed geographically in proportion to the population of the United States.

Emissions resulting from its use as a chemical intermediate were estimated by using the dimethylamine end-use emission factor of 0.001 lb lost/lb used. Emissions from rubber accelerator (8,800 lb) and optical brightener manufacturers (2500 lb) are shown in Tables 20-5 and 20-6 by region.

Total nationwide emissions of morpholine in 1978 from all sources are estimated to have been 10.028 million lb. A tabulation of the losses is shown in Table 20-7

Table 20-4. Morpholine Vent Parameter Data

	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Production[a]					
Process	3	40	0.33	150	10
Storage	8	20	0.17	80	
Fugitive[b]					
End-use[c] (chemical intermediate)					
Process	1	40	0.17	100	6
Storage	2	20	0.17	80	
Fugitive[d]					

[a] Building cross-section 5 m^2.

[b] Distributed over a 200 ft X 200 ft area.

[c] Building cross-section 50 m^2.

[d] Distributed over a 100 ft X 100 ft area.

Table 20-5. Morpholine Emission Estimates from Rubber Accelerator Producers[a]

Region	Number of Sites	Morpholine Emissions[b] (lb/yr)	(g/sec)[c]
New England	15	1380	0.020
Middle Atlantic	24	2210	0.032
East North Central	25	2300	0.033
South Atlantic	9	830	0.012
East South Central	18	1650	0.024
West South Central	5	460	0.007
Total	96	8800	

[a] See ref. 4.

[b] Based on morpholine emissions lost per site of 92 lb/yr using 0.001 lb morpholine lost/lb used.

[c] Based on 8760 hr/yr operation.

Table 20-6. Morpholine Emission Estimates from Optical Brightener Producers[a]

Region	Number of Sites	Morpholine Emissions[b] (lb/yr)	Morpholine Emissions[b] (g/sec)[d]	Average Emissions per Site[c] (lb/yr)
New England	8	175	0.003	22
Middle Atlantic	29	454	0.007	16
East North Central	31	833	0.012	27
West North Central	10	310	0.004	31
South Atlantic	13	286	0.004	22
East South Central	4	32	nil	8
Pacific	33	317	0.005	10
Total	128	2500		

[a] See ref. 5.

[b] Based on 0.001 lb morpholine lost/lb used.

[c] Emissions allocated by total number of employees per region.

[d] Assumes 8760 hr/yr operation.

Table 20-7. 1978 Morpholine Nationwide Emissions

Source	Estimated National Emission (M lb/yr)
Production	0.014
Rubber chemicals	0.009
Corrosion inhibitor	7.500
Optical brightener	0.003
Polishes and waxes	2.500
Miscellaneous	0.002
Exports	0
Total	10.028

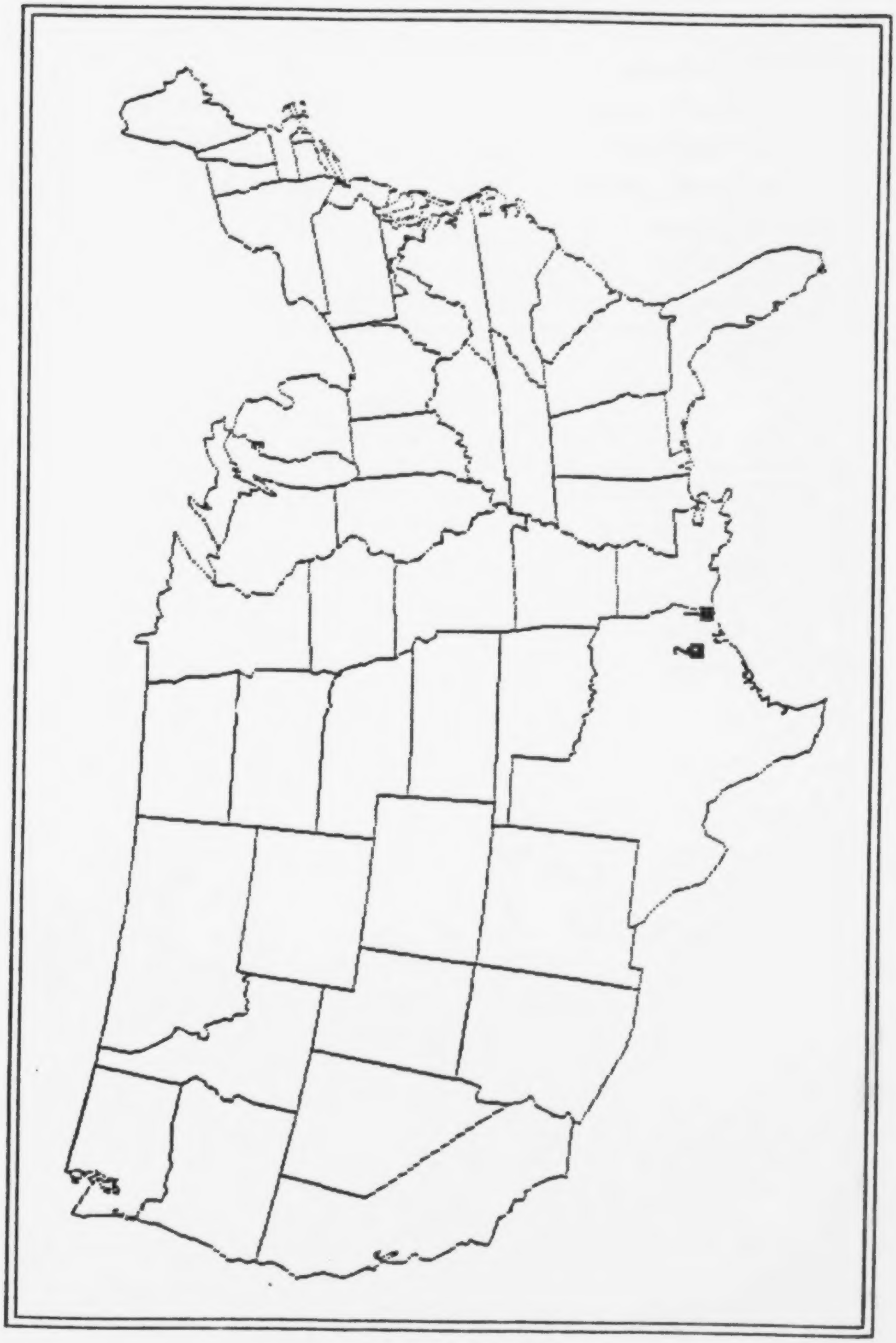


FIGURE 20-1. SPECIFIC POINT SOURCES OF MORPHOLINE EMISSIONS

TABLE 20-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF MORPHOLINE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE*	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	JEFFERSON	PORT NECHES, TX	29 57 45	093 56 00	12917	1	1	.094464	.003744	.000360
2	JEFFERSON	CONROE, TX	30 18 50	095 23 06	12960	1	1	.094464	.003744	.000360

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* The chemical plants producing morpholine are the only type of specific point sources for its emissions.

TABLE 20-9. EXPOSURE AND DOSAGE OF MORPHOLINE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) · persons]
0.0005	0	.0000219
0.00025	1,380	.372
0.0001	26,481	3.4
0.00005	106,662	8.8
0.000025	200,117	12.5
0.0000125*	239,277	13.4

---

*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 20-10. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF MORPHOLINE

Region	Resins Production		Wire Enamel Solvent	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00132	15	0.000315	8
Middle Atlantic	0.00132	24	0.000225	29
East North Central	0.00132	25	0.000387	31
West North Central	0.00132	0	0.000446	10
South Atlantic	0.00132	9	0.000317	13
East South Central	0.00132	18	0.000115	4
West South Central	0.00132	5	0	0
Mountain	0.00132	0	0	0
Pacific	0.00132	0	0.000138	33

TABLE 20-11. NITROSOMORPHOLINE EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF MORPHOLINE

Concentration Level (ng/m^3)	Population Exposed (10^3 persons)			Dosage [10^3(ng/m^3)·persons]		
	Accelerator Production	Brightener Production	U.S. Total	Accelerator Production	Brightener Production	U.S. Total
0.025	0.16	0	0.16	0.004	0	0.004
0.010	7.87	0	7.87	0.102	0	0.102
0.0050	91.5	0.54	92.0	0.602	0.003	0.605
0.0025	--	--	--	2.65	0.035	2.69
0.0010	--	--	--	16.8	0.33	17.1
0.00050	--	--	--	40.8	1.27	42.1
0.00025	--	--	--	58.0	6.57	64.5
0	--	--	--	736	23.7	97.3

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 20-12. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF MORPHOLINE

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	4.67×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	144.03 gm/sec
Corrosion inhibitor emissions	108 gm/sec
Wax application emissions	36 gm/sec
Miscellaneous	0.03 gm/sec
Nationwide mobile source emissions	0

TABLE 20-13. MORPHOLINE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.000100	21659620	3442.1	0.	100.0	0.	100.0	0.	0.
.000050	44606075	5073.2	0.	100.0	0.	100.0	0.	0.
.000025	72282642	6017.5	0.	100.0	0.	100.0	0.	0.
.000010	104863590	6572.1	0.	100.0	0.	100.0	.0	0.
.000005	123499379	6709.4	0.	100.0	0.	99.7	.3	0.
0.	158679135	6790.6	0.	100.0	0.	98.8	.6	.6

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TABLE 20-14. EXPOSURE AND DOSAGE SUMMARY OF NITROSOMORPHOLINE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)				Dosage [($\mu g/m^3$)·persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
0.00025	1,380	0	0	1,380	0.4	0	0	0.4
0.0001	26,481	0	21,659,620	--	3	0	3,442	3,445
0.00005	106,662	0	44,606,075	--	9	0	5,073	5,080
0.000025	200,117	160	72,282,642	--	13	0	6,017	6,030
0.00001	239,277	7,870	104,863,590	--	--	0.1	6,572	--
0.000005	--	92,000	123,499,379	--	--	0.6	6,709	--
0	--	--	158,679,135	--	13	97.3	6,791	6,900

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. "Chemical Products Synopsis on Morpholine," Mannsville Chemical Products (December 1977).

2. "Chemical Profile on Morpholine," Third Revision, Chemical Marketing Reporter (October 1, 1974).

3. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio, by Monsanto Research Corporation, Dayton, OH (April 1976).

4. 1979 Directory of Chemical Producers, United States of America, Stanford Research Institute, Menlo Park, CA.

5. "Soaps and Other Detergents," 1972 U.S. Census of Manufacturers, SIC Code 2841.

APPENDIX A-21 ----- Nickel

NICKEL CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 7440-02-0

Synonyms: Carbonyl nickle powder

Chemical Formula

Molecular Weight: 58.71 (atomic weight)

Molecular Formula: Ni - atomic number: 28

Molucular Structure: (atomic structure): face-centered cubic crystal

Chemical and Physical Properties

Physical State at STP: Solid-lustrous white, hard, ferromagnetic

Boiling Point: 2732°C to 2837°C

Melting Point: 1453°C to 1555°C

Density: 8.902 at 25°C/4°C

Vapor Pressure: N/A

Vapor Density: N/A

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): N/A

Atmospheric Reactivity

Transformation Products: Stable in air at ordinary temperatures. Burns in oxygen forming NiO. Slowly attacked by oil hydrochloric or sulfuric acid, readily attacked by nitric acid.

Reactivity Toward OH: Unreactive

Reactivity Toward O_3: Unreactive

Reactivity Toward Photolysis: N/A

Major Atmospheric Precursors: N/A

Formation Reactivity: 0.018% abundance in earth's crust. Occurs free in meteorites. Found in many ores (e.g. pentlandite (FeN•)gSo).

I. SOURCES

A. PRODUCTION

There were only two domestic nickel mineral production sites in the United States in 1976 the last year for which data are available.[1]

Hanna Mining Company at Riddle, Oregon, produced an estimated 10,300 tons of nickel primarily from laterite ore, although part of the production was from scrap. The second producer, AMAX, Inc., at Port Nickel, Louisiana, produced an estimated 13,300 tons of nickel derived from nickel-copper matte imported from Botswana.[2]

The remainder of the nickel consumed in the United States was imported. This amounted to 188,100 tons in 1973. Table 21-1 shows the estimated salient statistics.[1]

The two producing site locations are shown in Table 21-2.[1,2]

B. USES

The primary end-use of nickel is in the manufacture of steel and other ferrous alloys. An estimated 43,600 tons of nickel was consumed for steel manufacture. A total of 19,100 tons was consumed in the manufacture of other ferroalloys. Nonferroalloys consumed 54,800 tons of nickel; electroplating used an estimated 28,700 tons of nickel. Other smaller uses of the mineral were in cast irons, chemicals, batteries, and ceramics.

An estimated 162,900 tons of primary nickel was consumed as shown in Table 21-3.[3]

C. INCIDENTAL SOURCES

Incidental sources of nickel emissions include coal- and oil-fired boilers, coke ovens, diesel fuel burning, and the gray iron foundry industry. The boilers include industrial, electric utility power plant, commercial, and residential types. Nickel emissions originate as impurities from oil and coal when they are burned in the boilers, in coke ovens, or as diesel fuel. Table 21-4[3,4] shows the estimated consumption of oil and coal in 1973 by use category. Table 21-5[5] indicates the percent breakdown of the coal and oil used by the electric utilities by region.

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Table 21-1. Nickel Salient Statistics*

	1000 ton/yr
U.S. Plant production	
Primary	13.9
Secondary	13.3
Imports	188.1
Exports	
Primary stock	31.6
Net consumption	172.6

*See ref. 1.

Table 21-2. Domestic Nickel Producers*

Company	Location	Production (ton/yr)	Geographic Coordinates (latitude/longitude)
Primary			
Hannah Mining	Riddle, OR	13,900	42 55 02/123 24 60
Secondary			
AMAX, Inc.	Port Nickel, LA	13,300	29 52 35 /89 57 26

---

[*] See refs. 1 and 2.

Table 21-3. Nickel End-Use Consumption[a]

End-use[b]	Usage 1000 ton/yr	Percent Usage
Steel		
Stainless and heat resistant	48.6	29.8
Alloys (excludes stainless)	19.1	11.7
Super alloys	9.1	5.6
Nickel-copper/copper-nickel alloys	7.4	4.5
Permanent magnet alloys	5.8	3.6
Other nickel and nickel alloys	32.5	20.0
Cast irons	4.0	2.5
Electroplating	28.7	17.7
Chemicals and chemical uses	2.6	1.6
Others[c]	4.1	3.1
Total	162.9	100.0

[a] See ref. 1.

[b] Exclusive of scrap; primary nickel only.

[c] Includes batteries, ceramics, and other alloys containing nickel.

Table 21-4. 1978 United States Oil and Coal Consumption*

Users	Coal Consumption (million tons)	Oil Consumption (million bbls)
Electrical utilities	480	646
Industry	55	671
Coke ovens	75	---
Residential/Commercial	8	707
Diesl fuel	---	327
Total	618	2351

---

[*] See refs. 3 and 4.

Table 21-5. Electrical Utility Power Plant Locations and Usage of Coal and Oil by Geographic Region*

Region	Number of Coal Consuming Sites	Percentage of Total U.S. Coal Consumption	Number of Oil Consuming Sites	Percentage of Total U.S. Oil Consumption
New England	9	0.7	35	9.4
Middle Atlantic	51	11.3	70	27.9
East North Central	156	33.9	110	5.9
West North Central	111	9.4	85	0.7
South Atlantic	61	19.6	97	31.4
East South Central	44	16.3	26	2.0
West South Central	3	1.3	100	4.8
Mountain	38	6.8	44	2.2
Pacific	1	0.7	33	15.7
Total	474	100.0	600	100.0

*See ref. 5.

II. EMISSION ESTIMATES

A. PRODUCTION

The primary source of emission data for this summary was the Survey of Emissions and Controls for Hazardous and Other Pollutants, prepared for the Environmental Protection Agency by the Mitre Corp.[6] In this report, it is estimated that emissions resulting from electroplating, chemical use, and miscellaneous uses are negligible due to control techniques.

Production emissions as shown in Table 21-6 are estimated to have been 236,060 lb.

B. USES

Emissions from nickel use also include incidental emissions of nickel inherent in the metals processed. The emissions from its use to produce iron and steel are shown in Table 21-7 by geographic region. They totaled 231,000 lb. Emissions are based on an emisson factor of 0.0000011 lb nickel lost/lb iron steel produced assuming pigiron production of 105,000,000 tons in 1978.

Emissions from ferroalloy manufacture totaled 828,000 lb and are shown in Table 21-8 by geographic region. Emission estimates were based on an emission factor of 0.000217 lb nickel lost per lb ferro alloy produced.[6] Ferro alloy production was estimated to be 1,910,000 tons in 1978. Emissions are distributed by geographic region. in Table 8.

Nickel emissions from gray iron foundries totaled 185,800 lbs based on an emission factor of 0.00000516 lb nickel lost per lb of hot metal produced assuming 18,000,000 ton hot metal was preduced in 1978. Emissions are distributed by region in Table 21-9.

Emissions from iron and steel and gray iron foundry sources were distributed by region based on the number of people employed in the basic industries.[7] Ferroalloys were distributed simply by the number of sites in each region.[8]

Table 21-6. Nickel Production Emissions

Company	Location	Total Emissions (lb/yr)	Total Emissions (g/sec)
Hannan Mining [a]	Riddle, OR	20,600	.30
AMAX, Inc.[b]	Port Nickel, LA	215,460	3.10
		236,060	

[a] See ref. 9

[b] Based on 0.0081 lb nickel emitted/lb nickel produced. "C" derived from published data (see ref. 6).

Table 21-7. Nickel Emission Estimates from Iron and Steel Manufacturing Sites[a]

Region	Number of Sites	Nickel Emissions (lb/yr)	Average Emissions Per Site (lb/yr)	Average Emissions Per Site (g/sec)[b]
New England	10	1,380	138	0.003
Middle Atlantic	65	71,333	1098	0.016
East North Central	84	96,789	1152	0.017
West North Central	5	2,539	508	0.008
South Atlantic	22	20,561	935	0.013
East South Central	25	15,704	628	0.009
West South Central	12	5,313	443	0.007
Mountain	2	5,547	2774	0.040
Pacific	32	11,784	368	0.005
Total	257	231,000	899	0.013

[a] See ref. 7.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.0000011 lb nickel lost per lb iron/steel produced "C" (see ref. 6).

Table 21-8. Nickel Emission Estimates from Ferro-Alloy Production Sites[a]

Region	Number of Sites	Nickle Emissions (lb/yr)[b]	Nickle Emissions (g/sec)[c]
New England	0	0	0
Middle Atlantic	12	194,820	2.80
East North Central	8	129,880	1.87
West North Central	1	16,235	0.23
South Atlantic	8	129,880	1.87
East South Central	13	211,055	3.04
West South Central	1	16,235	0.23
Mountain	4	64,940	0.93
Pacific	4	64,940	0.93
Total	51	828,000	

[a] See ref. 8.

[b] Based on an average emission rate of 16,235 lb/yr per site. (0.23 g/sec)

[c] Based on 8760 hours per year operation.

[d] Based on an emission factor of 0.000217 lb nickel lost/lb ferro-alloy produced "C" (see ref. 6).

Table 21-9. Nickel Emission Estimates from Gray Iron Foundry Sites[a]

Region	Number of Sites	Nickel Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	13	4,645	357	0.005
Middle Atlantic	42	17,095	407	0.006
East North Central	129	96,800	750	0.011
West North Central	29	10,590	365	0.005
South Atlantic	22	13,750	625	0.009
East South Central	37	21,925	593	0.009
West South Central	19	9,290	489	0.007
Mountain	5	2,230	446	0.006
Pacific	28	9,475	338	0.005
Total	324	185,800[c]	573	0.008

[a] See ref. 7 .

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.00000516 lb nickel lost per lb of hot metal "C" (see ref. 6).

Emissions from nonferrous alloy manufacture were estimated to be 142,600 lb based on an emission factor of 0.000012 lb nickel lost/lb produced and 5,942,000 tons of nonferrous alloy produced in 1978. Specific source locations could not be identified to allow for a regional distribution.

Nickel emissions resulting from electrical utility power plants are shown for coal-fired operations in Table 21-10 and for oil-fired operations in Table 21-11. Coal-fired plants had emissions of 316,800 lb[6] and oil fired plants 8,139,600 lb.[6]

These emissions were calculated by multiplying the emission factors shown in Tables 21-10 and 21-11 by the coal and oil used shown in Table 21-4. The emissions were distributed by region according to the usage percentages shown in Table 21-5

Nickel emissions from coke ovens were estimated to have been 123,000 lb as shown in Table 21-12.[9] This estimate is based on an emission factor of 0.00000082 lb nickel lost per lb of coal used to manufacture coke.[6]. Total emissions were distributed by the number of sites in each region.

The remaining incidental sources of nickel emissions are from other sources which burn oil or coal. Emissions from coal- and oil-fired industrial boilers were estimated to have been 36,300 lb and 6,481,860 lb respectively derived from an emission factor of 0.00000033 lb nickel lost per lb of coal burned[6] and 0.00023 lb of nickel lost per gal of oil burned.[6] Emissions from residential and commercial coal and oil heating were estimated to be 2,400 lb and 3,860,220 lb respectively derived from an emission factor of 0.00000015 lb nickel lost per lb of coal burned[6] and 0.00013 lb of nickel lost per gal of oil burned.[6] Diesel fuel consumption generated an estimated 1,785,420 lb of nickel emissions based on emission factor of 0.00013 lb nickel lost per gal of diesel fuel consumed.[6] Source locations for all of these incidental categories are considered too numerous and too diverse to pinpoint regional distributions.

Vent parameter data for all nickel emission sources are shown in Table 21-13.

Table 21-14 presents a summary of nickel emissions. Total nationwide nickel emissions are estimated to have been 22,369,060 lb in 1978.

Table 21-10. Nickel Emissions from Electrical Utility Power Plants (coal-fired)[a]

Region	Number of Sites	Nickel Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	9	2,220	245	0.004
Middle Atlantic	51	35,800	700	0.010
East North Central	156	107,395	690	0.010
West North Central	111	29,775	270	0.004
South Atlantic	61	62,095	1020	0.015
East South Central	44	51,640	1175	0.017
West South Central	3	4,115	1370	0.020
Mountain	38	21,540	565	0.008
Pacific	1	2,220	2220	0.032
Total	474	316,800	670	

[a] See ref. 5.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.00000033 lb nickel emitted per lb coal burned "C" from published source (see ref. 6).

Table 21-11. Nickel Emissions from Electrical Utility Power Plants (oil-fired)[a]

Region	Number of Sites	Nickel Emissions (lb/yr)	Average Emissions/Site (lb/yr)	Average Emissions/Site (g/sec)[b]
New England	35	765,125	21,860	0.31
Middle Atlantic	70	2,270,945	32,440	0.47
East North Central	110	480,235	4,365	0.06
West North Central	85	56,960	670	0.01
South Atlantic	97	2,555,830	26,350	0.38
East South Central	26	162,790	6,260	0.09
West South Central	100	390,700	3,905	0.06
Mountain	44	179,075	4,070	0.06
Pacific	33	1,277,920	38,725	0.56
Total	600	8,139,600[c]	13,566	

[a] See ref. 5.

[b] Based on 8760 hr/yr operation.

[c] Based on an emission factor of 0.000300 lb nickel emitted per gal oil burned. "C" Published data (see ref. 6).

Table 21-12. Nickel Emissions from Coke Oven Operations (coal burning)[a]

Region	Number of Sites	Total Emissions (lb/yr)
New England	0	0
Middle Atlantic	15	30,245
East North Central	25	50,410
West North Central	3	6,050
South Atlantic	4	8,065
East South Central	9	18,145
West South Central	2	4,035
Mountain	2	4,035
Pacific	1	2,015
Total	61	123,000[b,c]

[a] See ref. 9.

[b] Based on an emission factor of 0.00000082 lb nickel emitted/lb coal burned (see ref. 6).

[c] Average emission rate per site 2016 lb/yr (0.029 g/sec).

Table 21-13. Nickel Vent Parameters*

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (fps)
Power plant	1	400	16	200	90
Iron and steel	2	80	1	200	40
Ferro-alloy	1	80	1	200	40
Gray iron foundry	1	150	2	200	40
Coke oven	2	30	1	300	15

*Building cross-section all sources-200 M^2.

Table 21-14. 1978 Nickel Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Nickel mining/smelting	236,060
Iron and steel manufacturing	231,000
Ferroalloys	828,000
Non-ferroalloys	142,600
Gray Iron Foundry	185,800
Electroplating	Negligible
Chemicals	Negligible
Others	Negligible
Power Plants	
Coal	316,800
Oil	8,139,600
Industrial Boilers	
Coal	36,300
Oil	6,481,860
Residential/Commercial	
Coal	2,400
Oil	3,860,220
Coke ovens (coal)	123,000
Diesel fuel (oil)	1,785,420
Total	22,369,060

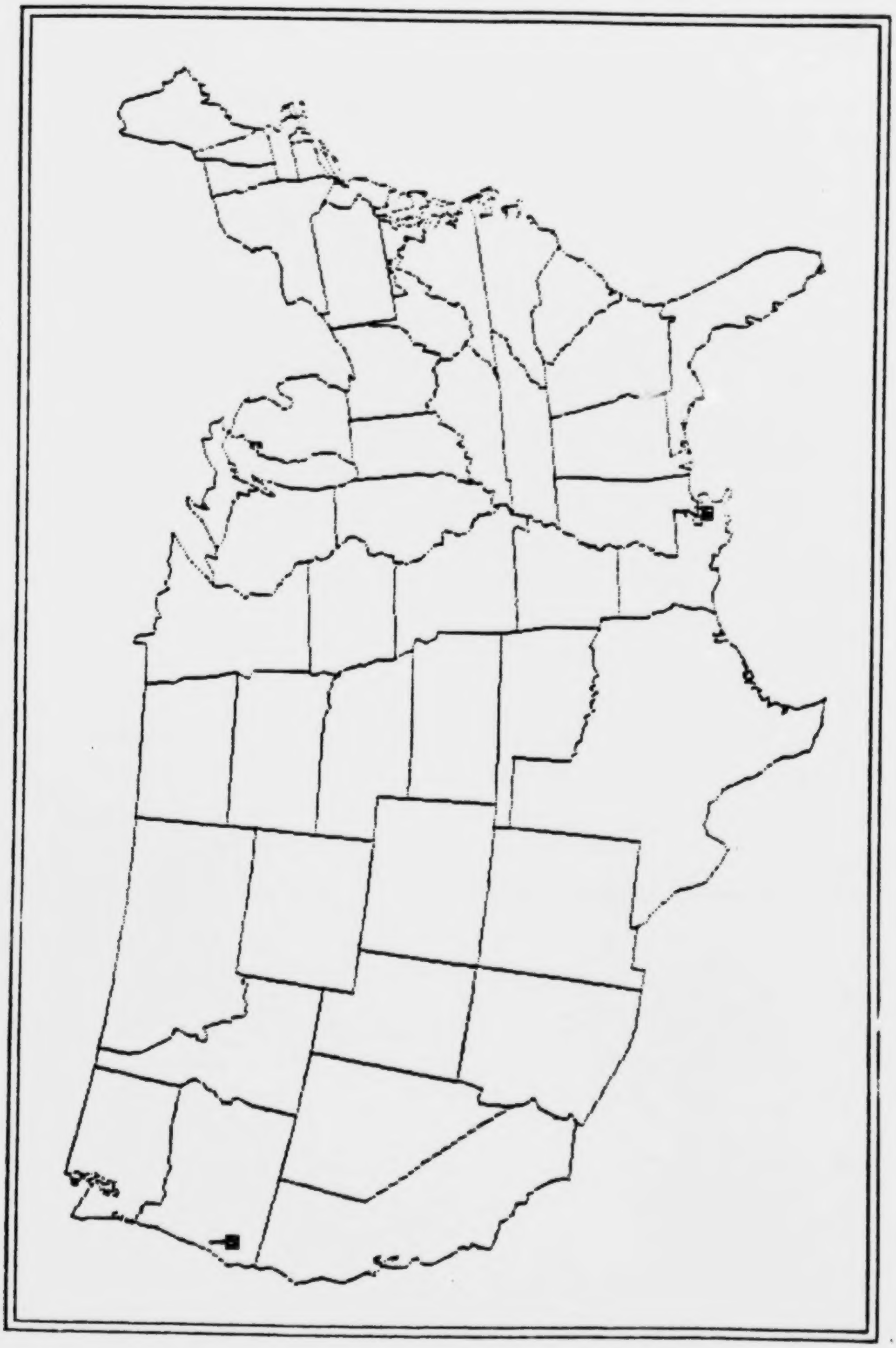

FIGURE 21-1. SPECIFIC POINT SOURCES OF NICKEL EMISSIONS

Table 21-15. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF NICKEL

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE* TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	HANNAH MINING	RIDDLE, OR	42 55 02	123 25 00	24221	1	1	.296296	0.	0.
2.	AMAX	PORT NICKEL, LA	29 52 35	089 57 26	12958	1	1	3.099029	0.	0.

---

* The only specific point sources of nickel emissions are the two smelters producing nickel.

Vent: Parameters

Parameter	Hannah Mining [a]	AMAX
vent height	18.6 m	30 m
effective building cross section	200 m^2	200 m^2
vent diameter	4.5 m	0.6 m
vent velocity	2.8 m/s	14 m/s
vent temperature	356° K.	477° K.

[a] See ref. 9.

TABLE 21-16 EXPOSURE AND DOSAGE OF NICKEL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
5.53	2	10
5	6	30
2.5	132	441
1	773	1,290
0.5	1,496	1,810
0.25	2,586	2,160
0.1	99,664	16,200
0.05	448,132	38,600
0.025	706,032	49,700
0.01	708,128	49,700
0.00111*	720,524	49,700

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 21-17. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF NICKEL

Region	Iron/Steel Production		Ferroalloys Production		Gray Foundry		Power Plant (Coal)		Power Plant (Oil)		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of-Sites	Emissions/Site (gm/sec)	Number of-Sites
New England	0.00199	10	0.234	0	0.00514	13	0.00353	9	0.315	35	0.029	0
Middle Atlantic	0.0158	65	0.234	12	0.00586	42	0.0101	51	0.467	70	0.029	15
East North Central	0.0166	84	0.234	8	0.0108	129	0.00994	156	0.0629	110	0.029	25
West North Central	0.00732	5	0.234	1	0.00526	29	0.00389	111	0.00965	85	0.029	3
South Atlantic	0.0135	22	0.234	8	0.0090	22	0.0147	61	0.0379	97	0.029	4
East South Central	0.00904	25	0.234	13	0.00854	37	0.0169	44	0.0901	26	0.029	9
West South Central	0.00638	12	0.234	1	0.00704	19	0.0197	3	0.0562	100	0.029	2
Mountain	0.0399	2	0.234	4	0.00642	5	0.00814	38	0.0586	44	0.029	2
Pacific	0.00523	32	0.234	4	0.00487	28	0.0320	1	0.0558	33	0.029	1

TABLE 21-18. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF NICKEL

	Population Exposed (10^3 persons)							Dosage [10^3($\mu g/m^3$)·persons]						
Concentration Level ($\mu g/m^3$)	Iron/ Steel Production	Ferro- alloys Production	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Coke Oven	U.S. Total	Iron/ Steel Production	Ferro- alloys Production	Gray Iron Foundry	Power Plant (Coal)	Power Plant (Oil)	Oven Coke	U.S. Total
1	0	3.4	0	0	0	0	3.4	0	3.9	0	0	0	0	3.9
0.5	0	44	0	0	44	0.5	88	0	31	0	0	27.3	0.25	59
0.25	0	230	0	0	233	7.3	470	0	94	0	0	92	2.4	189
0.1	0	1,030	0	0	2,040	71	3,140	0	224	0	0	355	11	590
0.05	--	--	--	--	--	--	--	2.3	344	0	0	587	23	956
0.025	--	--	--	--	--	--	--	12	435	0.6	0.02	932	39	1,420
0.01	--	--	--	--	--	--	--	42	639	10	2	1,330	63	2,090
0.005	--	--	--	--	--	--	--	70	805	25	7	1,760	80	2,730
0.0025	--	--	--	--	--	--	--	98	934	43	16	2,130	103	3,330
0.001	--	--	--	--	--	--	--	141	982	65	32	2,610	135	3,960
0.0005	--	--	--	--	--	--	--	183	986	86	43	2,740	161	4,200
0	--	--	--	--	--	--	--	261	986	159	108	2,840	177	4,350

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 21-19. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF NICKEL

Parameter	Value
Daytime decay rate (K_d)	0
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	55.62 gm/sec
Nationwide nonheating stationary source emissions (E_N)	95.91 gm/sec
Nonferroalloys production	2.05 gm/sec
Industrial boiler combustion	93.86 gm/sec
Nationwide mobile source emissions (E_M)	25.71 gm/sec
Raito of truck emissions to auto emissions (R_M)	3

TABLE 21-20. NICKEL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.500000	505140	349680.9	19.0	73.9	7.1	100.0	0.	0.
.250000	9149730	3565444.6	39.7	55.8	4.6	100.0	0.	0.
.100000	30126880	6710390.7	37.0	55.3	7.7	100.0	0.	0.
.050000	81697926	10154411.8	35.2	55.7	9.1	97.6	1.0	1.4
.025000	131790074	12041708.9	34.4	55.8	9.8	94.6	2.4	3.0
0.	158679135	12506833.2	34.1	55.9	10.0	92.7	2.7	4.7

TABLE 21-21. EXPOSURE AND DOSAGE SUMMARY OF NICKEL

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
5	6	0	0	6	30	0	0	30
2.5	132	0	0	132	441	0	0	441
1	773	3,400	0	4,173	1,290	3,900	0	5,190
0.5	1,496	88,000	505,140	594,636	1,810	59,000	349,681	410,491
0.25	2,586	470,000	9,149,730	9,622,316	2,160	189,000	3,565,444	3,756,604
0.1	99,664	3,140,000	30,126,880	33,366,544	16,200	590,000	6,710,390	7,316,590
0.05	448,132	--	81,697,926	--	38,600	956,000	10,154,411	11,149,011
0.025	706,032	--	131,790,074	--	49,700	1,420,000	12,041,708	13,511,408
0.01	--	--	--	--	--	2,090,000	--	--
0	720,524	--	158,679,135	--	49,700	4,350,000	12,506,833	16,906,533

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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10. The Hannah Mining Company, (Samuel E. Malourh), Personal Communication in response to publication of the first draft of this report (June 1981).
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APPENDIX A-22 ----- Nitrobenzene

NITROBENZENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 98-95-3

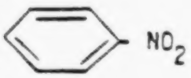
Synonyms: Nitrobenzol; Mononitrobenzene

Chemical Formula

Molecular Weight: 123.11

Molecular Formula: $C_6H_5\ NO_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid/oily liquid, colorless; volatile oil; almond odor

Boiling Point: 210.8°C at 760 mm

Melting Point: 5.7°C

Density: 1.2037 at 20°C/4°C

Vapor Pressure: 0.284 mm at 25°C

Vapor Density: 4.25

Solubility: Slightly soluble (10 g/l at 20°C; 2.04 g/l in H_2O at 30°C).

Log Partition Coefficient (Octanol/H_2O): 1.88

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 1/2 butane

Reactivity Toward O_3: Relatively unreactive, t 1/2 = 11 yr.

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Nitrobenzene ($C_6H_5NO_2$) is currently produced in the United States by the direct nitration of benzene with a mixture of nitric acid, sulfuric acid, and water.[1,2] The quantity of organic by-products formed, primarily nitrated phenols, is only about 0.02 wt % of the nitrobenzene produced.

There are currently five companies producing nitrobenzene at six locations in the United States. The locations of the plants and the 1978 capacity and estimated production level for each plant are shown in Table 22-1.[1,2,3] An estimated 795 million lb of nitrobenzene was produced in 1978.

B. USES

Approximately 98% (784 million lb) of the nitrobenene produced in 1978 was consumed captively for the manufacture of aniline. An estimated 6 million lb. (0.5%) of the nitrobenzene production was used as a solvent in cellulose ether manufacture and as a selective solvent in the petroleum industry. A very small portion, 4 million lb, was used as a chemical intermediate to produce dichloroanilines and dinitrobenzenes. Uses are summarized in Table 22-2.[1,2] Specific chemical intermediate, nitrobenzene user site locations are shown in Table 22-3[5].

II. EMISSION ESTIMATES

A. PRODUCTION AND USE TO MAKE ANILINE

Estimated production losses are shown in Table 22-5 for each of the six producing locations. Total emissions of nitrobenzene resulting from its production and subsequent use to produce aniline are estimated to have been 257,000 lb in 1978.[5] Process emissions of nitrobenzene originate from the reactor and separator vents, from the wash and neutralization vents, and from the nitrobenzene stripper. Other associated emission components include nitrated phenols which leave via the wastewater effluent and benzene. It is estimated that nitrobenzene constitutes roughly 20% of the total volatile organic compounds emitted from nitrobenzene production and aniline manufacturing facilities.[5] Storage emissions

Table 22-1. Production of Nitrobenzene[a]

Source	Location	1978 Estimated Production[b] (million lb)	1978 Estimated Capacity (million lb)	Geographic Coordinates N. Latitude/W. Longitude
American Cyanamid	Willow Island, WV	55.2	85	39 21 50/ 81 18 50
Du Pont	Beaumont, TX	243.3	375	30 00 51/ 94 01 40
	Gibbstown, NJ	129.8	200	39 49 50/ 75 15 50
First Chemicals	Pascagoula, MS	227.1	350	30 21 20/ 88 32 55
Mobay Corp.	New Martinsville, WV	87.6	135	39 44 50/ 80 50 50
Rubicon	Geismar, LA	51.9	80	30 12 00/ 91 00 30
Total		794,8	1225	

[a] See refs 1—3.

[b] The distribution of production for each producer is determined by the ratio of total U.S. production/total capacity as compared to individual capacity.

Table 22-2. 1978 Nitrobenzene Consumption by End Use*

End Use	Percent of Total Consumption	End Use Consumption ($\bar{M}$ lb)
Aniline	99	784
Solvent petroleum industry)	0.5	6
Chemical intermediate (dichloroanilines, dinitrobenzenes)	0.5	4
Total	100.0	794

*See refs 1 and 2.

Table 22-3. Nitrobenzene Chemical Intermediate User Locations*

Source	Location	Geographic Coordinates Latitude/Longitude
2,4-Dichloroaniline		
Eastman Kodak Company	Rochester, NY	43 12 01/77 37 58
3,4-Dichloroaniline		
Blue Spruce Co.	Bound Brook, NJ	40 32 10/76 29 18
Du Pont	Deepwater, NJ	39 41 25/75 30 35
Dinitrobenzene sulfonic acid		
Toms River Chem.	Toms River, NJ	39 58 14/74 12 30

*See ref 4.

Table 22-4. 1978 Nitrobenzene Emissions from Both Nitrobenzene and Aniline Production[a]

Company	Location	1978 Production ($\overline{\text{M}}$ lb)	Process Emissions (lb X 10^4)	Storage Emissions (lb X 10^4)	Fugitive Emissions (lb X 10^4)	Total Emissions[b] (lb X 10^4)	Total Emissions (g/sec)[c]
American Cyanamid	Willow Island, WV	55.2	0.04	0.03	1.71	1.79	0.26
Du Pont	Beaumont, TX	243.3	0.20	0.15	7.54	7.88	1.13
	Gibbstown, NJ	129.8	0.10	0.08	4.02	4.21	0.61
First Chemical	Pascagoula, MS	227.1	0.18	0.14	7.04	7.36	1.06
Mobay	New Martinsville, WV	87.6	0.07	0.05	2.73	2.84	0.41
Rubicon	Geismar, LA	51.9	0.04	0.03	1.61	1.68	0.24
Total		794.8	0.64	0.48	24.64	25.75	3.70

[a] From refs 1, 2, and 5 .

[b] Emission factor:

Process	0.000008	"A" from site visit data
Storage	0.000006	"A" from site visit data
Fugitive	0.000310	"A" from site visit data
Total	0.000324	

[c] Based on 8760 hr/yr operation.

represent the total losses from surge, final product, and feed storage tanks as well as loading and handling losses. Fugitive emissions are those that result from plant equipment leaks.

Vent stack data are shown in Table 22-5. Normally five process vents and five storage tank vents are sources of production and storage emissions. Usually nitrobenzene production facilities are "open-air" structures without walls and solid floors (i.e., steel grating). Only the control room area is enclosed. Fugitive losses are estimated to occur over a 130 ft X 260 ft area.[5]

B. USES

The emissions of nitrobenzene resulting from its use to make aniline were included in the nitrobenzene production losses.

The total quantity of nitrobenzene used in solvent applications, is eventually released to the atmosphere.

The 6,375,000 lb lost in refinery operations was distributed by geographic region. Allocation of emissions shown in Table 22-6 were made based on region refinery capacity.[6]

Nitrobenzene emissions resulting from its use as a chemical intermediate to produce dichloroanilines and dinitrobenzenes amounted to 6375 lb in 1978 based on an emission factor of 0.0015 lb lost/lb used.[7] Emissions are shown in Table 22-7. Total emissions were distributed evenly over all five sites in the absence of capacity data.

Total nationwide emissions of nitrobenzene in 1978 from all sources are estimated to have been 6.67 million lb. A tabulation of the losses is shown in Table 22-8 .

Table 22-5. Nitrobenzene Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Production[a,b]					
Process					
Reactors and separator	3	66	0.12	131	11.5
Wash and neutralization	1	36	0.10	113	12.5
Nitrobenzene stripper	1	66	0.08	89	6.6
Storage					
Nitrobenzene storage tank	5	40	0.12	104	-
Fugitive[c]					
Refinery[e]					
Process	1	30	0.33	120	7
Nitrobenzene chemical intermediate[d]					
Process	1	20	0.17	140	12
Storage	2	20	0.17	80	-
Fugitive[f]	-	-	-	-	-

[a] See ref 5.

[b] Building cross-section 50 m^2.

[c] Distributed over a 130 ft X 260 ft area.

[e] Building cross-section 200 m^2.

[f] Distributed over 100 ft X 100 ft area.

Table 22-6. Nitrobenzene Solvent Emissions from Petroleum Refineries by Region[a]

Region	Number of Sites	Refinery Capacity (bbl/day)	Nitrobenzene Emissions[b] (lb/yr)	Average Nitrobenzene Emissions per Site	
				(lb/yr)	(g/sec)[c]
New England	1	13,000	5,100	5,100	0.073
Middle Atlantic	16	1,552,620	595,425	37,215	0.536
East North Central	33	2,535,350	972,190	29,460	0.424
West North Central	19	844,753	323,850	17,045	0.245
South Atlantic	11	279,600	107,100	9,735	0.140
East South Central	16	645,686	247,350	15,460	0.223
West South Central	92	7,305,616	2,800,540	30,440	0.438
Mountain	42	683,076	262,010	6,240	0.090
Pacific	49	2,769,883	1,062,075	21,675	0.312
	279	16,629,584	6,375,000		

[a] See ref. 6.

[b] Assumes 50% of nitrobenzene solvent use is in refinery operations. Individual total emissions allocated per region by ratio of region refinery capacity compared to total U.S.A. refinery capacity.

[c] Assumes 8760 hr/yr operation.

Table 22-7. Nitrobenzene Emissions from Chemical Intermediate Users[a]

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[b] (lb/yr)	Total Emissions[b] (g/sec)[c]
Eastman Kodak	Rochester, NY	893	128	255	1275	0.018
Blue Spruce	Bound Brook, NJ	893	128	255	1275	0.018
Du Pont	Deepwater, NJ	893	128	255	1275	0.018
Toms River	Toms River, NJ	893	128	255	1275	0.018
Total		3567	512	1020	5100	

[a] See ref. 4.

[b] Based on nitrobenzene factor (lb lost/lb used). See ref. 7.

Process	0.00105	C	Derived from published source.
Storage	0.00015	C	Derived from published source.
Fugitive	0.00030	C	Derived from published source.
	0.00150		

[c] Based on 8760 hr/yr operation.

Table 22-8 . Estimated 1978 Nitrobenzene Nationwide Emission Losses

Source	Estimated National Emission (million lb/yr)
Production and consumption to make aniline	0.26
Solvent (petroleum industry)	6.4
Chemical intermediates (dichloroanilines and dinitrobenzenes)	0.01
Total	6.67

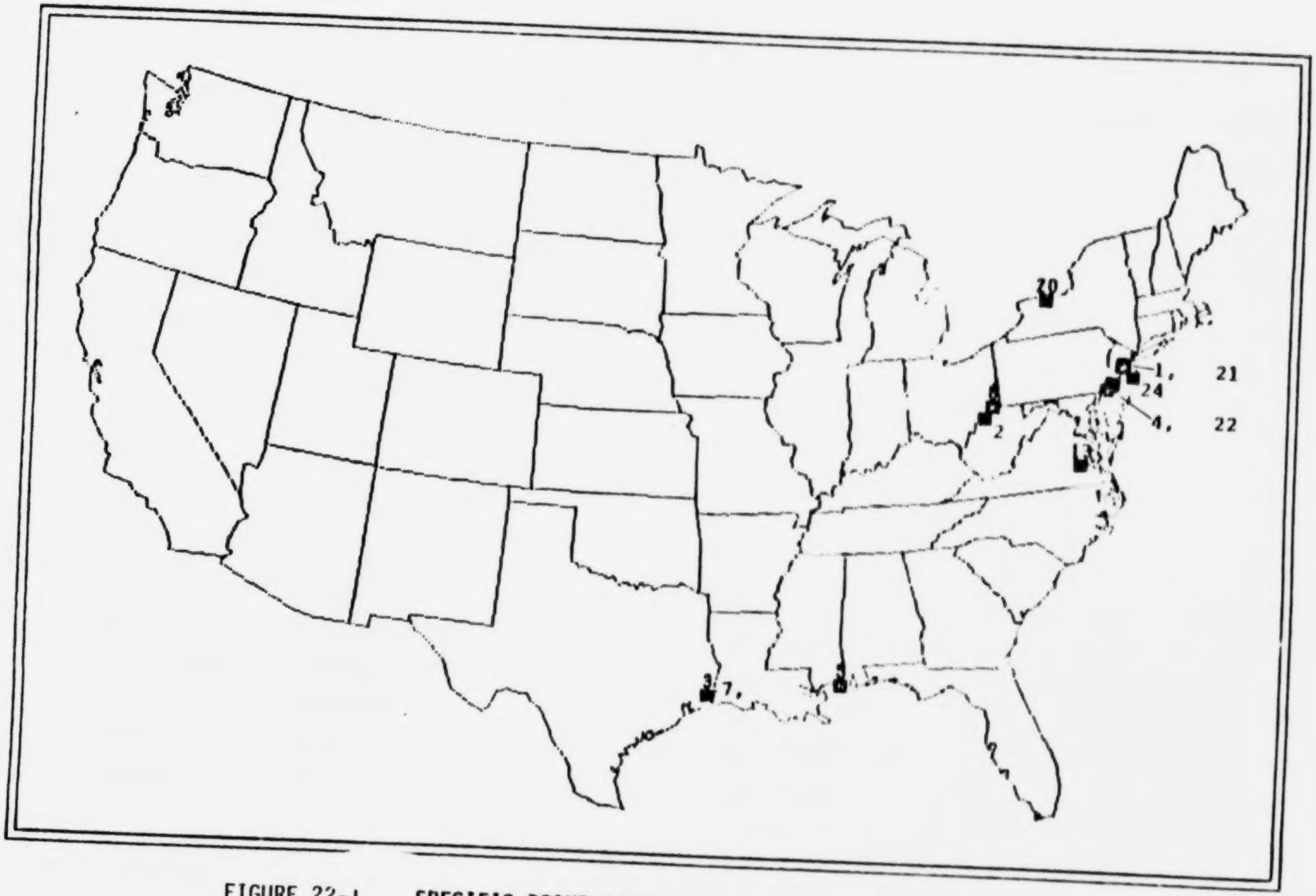

20
1,
21
24
4,
22
2
3
7,
5

FIGURE 22-1. SPECIFIC POINT SOURCES OF NITROBENZENE EMISSIONS

TABLE 22-9. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF NITROBENZENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
1	AMERICAN CYANAM	WILLOW ISLAND, WV	39 21 50	081 18 50	13736	1	1	.005760	.004320	.246240
2	DUPONT	BEAUMONT, TX	30 06 51	094 01 40	12917	1	1	.028800	.021600	1.085760
3	DUPONT	GIBBSTOWN, NJ	39 49 50	075 15 50	13739	1	1	.014400	.011520	.578880
4	FIRST CHEMICAL	PASCACOLA, MS	30 21 20	088 32 55	13820	1	1	.025920	.020160	1.013760
5	MOBAY	NEW MARTINSVILLE, WV	39 44 50	080 50 50	13736	1	1	.010080	.007200	.393120
6	RUBICON	GEISMAR, LA	30 12 00	091 11 30	12958	1	1	.005760	.004320	.231840
7	EASTMAN KODAK	ROCHESTER, NY	43 12 01	077 37 58	14771	2	2	.012859	.001843	

TABLE 22- 9 (Concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT TYPE*	SOURCE TYPE†	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
21	BLUE SPRUCE	BOUND BROOK NJ	40 32 10	074 29 18	14737	2	2	.012859	.001843	.003672
22	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	2	2	.012859	.001843	.003672
24	TOMS RIVER	TOMS RIVER, NJ	39 58 14	074 12 30	14706	2	2	.012859	.001843	.003672

* Plant Types:

Type 1: Plant produces nitrobenzene and aniline

Type 2: Plant produces nitrobenzene derivatives

† Source Types:

Type 1: Nitrobenzene and aniline production

Type 2: Derivative productions

TABLE 22-10. EXPOSURE AND DOSAGE OF NITROBENZENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) · persons]
5	4	23
2.5	106	370
1.0	1,359	2,200
0.5	5,825	5,150
0.25	14,435	8,000
0.10	47,471	13,500
0.05	86,600	16,200
0.025	175,991	19,200
3.6×10^{-5}*	4,510,613	39,000

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 22-11. EMISSIONS RATES AND NUMBER OF GENERIC POINT SOURCES OF NITROBENZENE (REFINERY SOLVENT USE)*

Region	Emissions/Site (gm/sec)	Number of Sites
New England	0.073	1
Middle Atlantic	0.536	16
East North Central	0.424	33
West North Central	0.245	19
South Atlantic	0.140	11
East South Central	0.223	16
West South Central	0.438	92
Mountain	0.090	42
Pacific	0.312	49

---

* Emissions parameters:

Vent height: 9 m
Building cross section: 200 m^2
Vent diameter: 0.10 m
Vent velocity: 2.1 m/sec
Vent temperature: 322°K

TABLE 22-12. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF NITROBENZENE (REFINERY SOLVENT USE)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [10^6 ($\mu g/m^3$) · persons]
10	0.71	0.01
5	8.1	0.06
2.5	43.4	0.18
1	192	0.41
0.5	482	0.61
0.25	--	0.91
0.1	--	1.41
0.05	--	1.75
0.025	--	2.17
0.01	--	3.26
0.005	--	3.75
0.0025	--	4.01
0.001	--	4.04
0.0005	--	4.05
0	--	4.05

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 22-13. EXPOSURE AND DOSAGE SUMMARY OF NITROBENZENE

Concentration Level ($\mu g/m^3$)	Population Exposed (persons) Specific Point Source	General Point Source	Area Source	U.S. Total	Dosage [($\mu g/m^3$) • persons] Specific Point Source	General Point Source	Area Source	U.S. Total
10		710	0			10,000	0	10,000
5	4	8,100	0	8,104	23	60,000	0	60,000
2.5	106	43,400	0	43,506	370	180,000	0	180,000
1	1,359	192,000	0	193,359	3,200	410,000	0	412,000
0.5	5,829	482,000	0	487,829	5,150	610,000	0	615,000
0.25	14,435	--	0	---	8,000	910,000	0	918,000
0.1	47,471	--	0	---	13,500	1,410,000	0	1,423,000
0.05	86,600	--	0	---	16,200	1,750,000	0	1,766,000
0.025	179,991	--	0	---	19,200	2,170,000	0	2,189,000
0.01	---	--	0	---	---	3,260,000	0	---
0.005	---	--	0	---	---	3,750,000	0	---
0.0025	---	--	0	---	---	4,010,000	0	---
0.001	---	--	0	---	---	4,040,000	0	---
0.0005	---	--	0	---	---	4,050,000	0	---
0	4,510,613	--	0	---	39,000	4,050,000	0	4,089,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

REFERENCES

1. E. M. Klapproth, "Aniline and Nitrobenzene," Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (January 1979).

2. "Chemical Product Synopsis on Nitrobenzene," Mannsville Chemical Products (March 1978).

3. "Chemical Profile on Nitrobenzene," Chemical Marketing Reporter (December 20, 1976).

4. Chemical Research Services, 1979 Directory of Chemical Producers, United States of America, Stanford Research Institute, Menlo Park, CA.

5. F. D. Hobbs and C. W. Stuewe, Hydroscience, Inc., Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry——Product Report on Nitrobenzene (on file at EPA, ESED, Research Triangle Park, NC (January 1979).

6. T. F. Killilea, "Petroleum Refinery Capacity by State," Chemical Economics Handbook, p. 229.3510B, Stanford Research Institute, Menlo Park, CA (January 1, 1978).

7. Special Project Report, "Petrochemical Plant Sites," prepared for Industrial Pollution Control Division, Industrial Environmental Research Laboratory, Environmental Protection Agency, Cincinnati, Ohio, by Monsanto Research Corporation, Dayton, Ohio (April 1976).

APPENDIX A-23 ----- PCB

PCB'S (POLYCHLORINATED BIPHENYLS) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: (a) 11097-69-1
(b) 11096-82-5

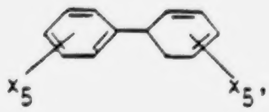
Synonyms:	(a)	(b)
	Aroclor 1254	Aroclor 1260
	Chlorinated biphenyls	PCB 1260
	Polychlorinated biphenyls	Kanechlor

Chemical Formula

Molecular Weight:

Molecular Formula: (exact composition unknown or undertermined)

Molecular Structure:



, x = Cl or H

Chemical and Physical Properties

Physical State at STP: Variable--mobile oily liquids; white crystalline solids; and hard noncrystaline resins

Boiling Point: 365° to 390°C

Melting Point:

Density: 1.495 to 1.505 at 65°C/15.5°C

Vapor Pressure: 1 mm at 25°C

Vapor Density:

Solubility: Slightly soluble (5.6×10^{-5} g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·: 5% butane

Reactivity Toward O_3: No Reaction

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

Polychlorinated biphenyls (PCBs) is a generic term used to describe the mixture of chlorinated biphenyl isomers (209 possible isomers) formed by the direct chlorination of biphenyl. PCBs were produced in the United States by the Monsanto Corporation at its Sauget, Illinois, plant, but PCB manufacture is currently banned in the United States.[1]

PCBs are no longer used or consumed for any kind of end-use in this country. Originally, PCBs had application as plasticizers, hydraulic fluids, pump oils, in carbonless carbon paper, and as a dielectric fluid in electrical equipment. In September of 1970, all end-uses of PCBs were restricted to only closed electrical systems such as transformers and capacitors.[2,3]

Currently, the only potential source of PCB emissions to the atmosphere is from the disposal of transformers and capacitors containing PCBs. Chemical landfills will be used to dispose of medium- and small-sized capacitors with negligible resulting emissions. Liquid PCBs, drained from transformers and large capacitors containing PCBs, will have to be incinerated per EPA regulations. Incineration will have some PCB emission potential.

The specific areas from which transformers and capacitors will have to be disposed and the quantity of PCBs generated by such incineration disposal are shown in Table 23-1.[2] Quantities of PCBs in excess of 30.02 million lb/yr requiring disposal would be landfilled. A list of proposed PCB incinerator site locations is shown in Table 23-2.

II. EMISSION ESTIMATES

Using the EPA's Versar Report[2] as a basis, an emission estimate was completed for incinerating a total of 30.02 million lb of PCBs at 12 locations within the United States (see Table 23-3). The total was apportioned over each site per the Versar Report assuming that all twelve sites would be in operation and that all PCBs incinerated would be done only at these 12 locations.

Table 23-1. Sources of PCBs for Incineration*
(million lb/yr)

Source	PCBs from Transformer Disposal	PCBs from Capacitor Disposal	Total PCBs from Closed Electrical Systems
Utilities	4.7	9.79	14.49
Large residential and commercial	1.6	6.78	8.38
Industrial	1.6	5.04	6.64
Private residential	0.5	0.01	0.51
Total	8.4	21.62	30.02

*See ref 2.

Table 23-2. Proposed PCB's Incinerator Site Locations[a]

Incinerator Location	Geographic Coordinates Latitude/Longitude
Bridgeport, NJ	39 46 00/75 22 00[b]
Deer Park, TX	29 45 50/95 09 00[b]
Baton Rouge, LA	30 33 35/91 15 30[b]
San Francisco, CA	38 00 00/122 00 00[c]
Los Angeles, CA	34 00 00/118 00 00[c]
Denver, CO	39 43 12/105 00 00[c]
Chicago, IL	41 52 00/87 43 38[c]
Sandusky, OH	40 26 15/82 41 21[c]
Atlanta, GA	33 45 17/84 22 51[c]
Richmond, VA	37 28 53/77 25 06[c]
Waterford, NY	42 49 03/73 45 13[b]
El Dorado, AR	33 14 38/92 18 45[c]

[a] See ref. 1.

[b] Represents existing incinerator sites.

[c] Represents geographic center of city or approximate center of chemical industry in proximity to that city.

Table 23-3. Incidental Sources of PCBs from Incinerator Sites after July 1, 1979[a]

Incinerator Location	PCB Solids Burned (million lb/yr)	PCB Emissions[b]			
		Case I		Case II	
		(lb/yr)	(g/sec)	(lb/yr)	(g/sec)[c]
Bridgeport, NJ[d]	5.91	5,910	0.106	591	0.011
Deer Park, TX[d]	2.12	2,120	0.038	212	0.004
Baton Rouge, LA[d]	0.99	990	0.018	99	0.002
San Francisco, CA[e]	1.60	1,600	0.029	160	0.003
Los Angeles, CA[e]	3.01	3,010	0.054	301	0.005
Denver, CO[e]	1.19	1,190	0.021	119	0.002
Chicago, IL[e]	2.75	2,750	0.049	275	0.005
Sandusky, OH[e]	3.83	3,830	0.069	383	0.007
Atlanta, GA[e]	5.21	5,210	0.094	521	0.009
Richmond, VA[e]	1.82	1,820	0.033	182	0.003
Waterford, NY[f]	0.10	100	0.002	10	-
El Dorado, AK[e]	1.49	1,490	0.027	149	0.003
Total	30.02	30,020		3,002	

[a] See ref 1.

[b] Case I = 99.90% removal efficiency; 0.001% of PCBs charged to the incinerator are released to the atmosphere.

Case II = 99.99% removal efficiency; 0.0001% of PCBs charged to the incinerator are released to the atmosphere.

[c] Assumes incinerator in operation 80% of the time, i.e., 7008 hr/yr.

[d] All three existing incinerators are owned by Rollins Environmental Services.

[e] Planned new incinerator installations.

[f] General Electric's Waterford, New York, incinerator to be used only for GE waste generated onsite.

The first three locations shown in Tables 23-2 and 23-3 are currently existing and are owned by Rollins Environmental Services. A fourth location, General Electrical, Waterford, NY, is also existing but will incinerate only PCB wastes generated onsite. All other sites shown in Tables 23-2 and 23-3 are proposed or planned.

Individual site emission estimates are based on two cases. Case I assumes a removal efficiency of 99.9% as specified in the initial EPA rules and regulations for PCB disposal,[4] and Case II assumes 99.99% removal efficiency, the level currently being recommended by RECRA.[5] Case II efficiencies have been demonstrated when burning liquid PCBs. Case I efficiencies have been achieved for incineration of solid PCB waste.

Emission rates are based on an average rate of 80% of total annual time. The other 20% downtime is caused by maintenance, refractory repair, and inventory interruptions.

Vent parameter data, representative of a typical incinerator system, are shown in Table 23-4.

Total estimated annual emissions of PCBs with all twelve incineration sites operating are estimated to be between 3000 and 30,020 lb/yr.

Table 23-4. PCB Incinerator Vent Parameters

Number of stacks	1
Vent height	175 ft
Vent diameter	2 ft
Discharge temperature (after water scrubber)	180°F
Velocity	60 ft/sec
Building cross-section	100 m^2

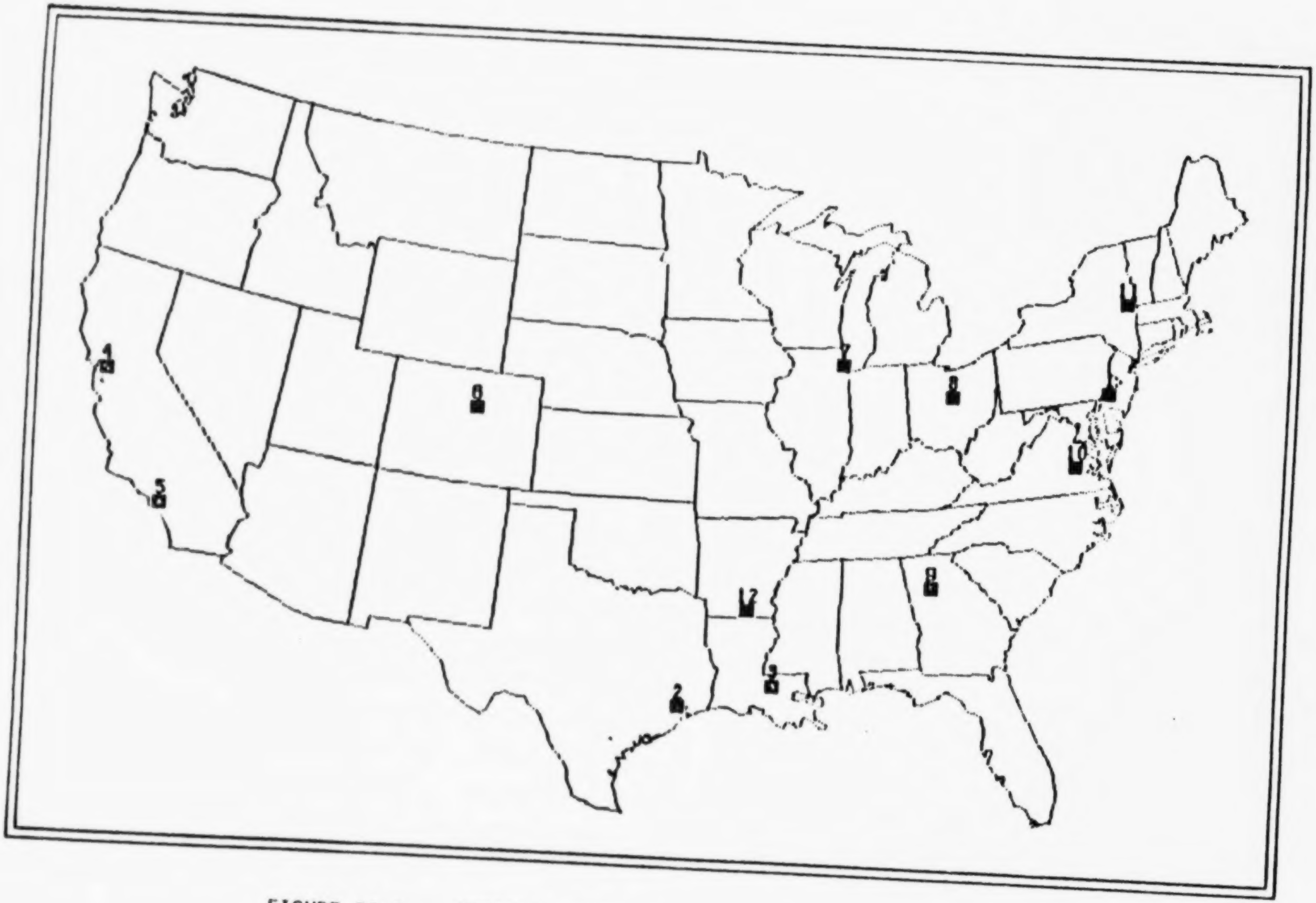

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FIGURE 23-1. SPECIFIC POINT SOURCES OF EMISSIONS OF PCBs

TABLE 23-5. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PCBs

NO.	SITE	LATITUDE	LONGITUDE	STAR STATION	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	BRIDGEPORT, NJ	39 46 00	075 22 00	13739	.068112	0.	0.
2	DEER PARK, TX	29 43 50	095 09 00	12906	.024400	0.	0.
3	BATON ROUGE, LA	30 33 33	091 15 30	13970	.011376	0.	0.
4	SAN FRANCISCO, CA	33 00 00	122 00 00	23234	.018432	0.	0.
5	LOS ANGELES, CA	34 00 00	118 00 00	23174	.034704	0.	0.
6	DENVER, CO	39 43 12	105 00 00	23062	.136800	0.	0.
7	CHICAGO, IL	41 52 00	087 43 38	94846	.031680	0.	0.
8	SANDUSKY, OH	40 26 15	083 41 21	14891	.044064	0.	0.
9	ATLANTA, GA	33 45 17	084 22 51	13874	.068048	0.	0.
10	RICHMOND, VA	37 28 53	077 25 06	13740	.021024	0.	0.
11	WATERFORD, NY	42 49 03	073 45 13	14735	.001152	0.	0.
12	EL DORADO, AK	33 14 38	092 18 43	93992	.017136	0.	0.

528

TABLE 23-6. EXPOSURE AND DOSAGE OF PCBs RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) • persons]
0.25	231	65
0.10	2,749	435
0.05	6,936	708
0.025	33,510	1,650
0.010	165,571	3,570
0.005	443,520	5,490
0.0025	959,598	7,240
0.0010	2,349,660	9,400
0.0005	4,203,743	10,700
0.00025	7,286,678	11,800
0.00010	10,592,456	12,300
7.7×10^{-7}*	12,024,404	12,400

---

* The lowest annual average concentration occurring within 20 km of the specific point source.

REFERENCES

1. A. K. Ahmed, "PCB in the Environment," Environment 18 (2), p. 7, March 1976.

2. "Microeconomic Impacts of the Proposed Marketing and Disposal Regulations for PCBs," EPA 560/6-77-013, U.S. Environmental Protection Agency, Office of Toxic Substances, Washington, D.C. (April 1977).

3. "Microeconomic Impacts of the Proposed PCB Ban Regulations," EPA 560/6-77-035, U.S. Environmental Protection Agency, Office of Planning and Management, Washington, D.C. (May 1978).

4. Environmental Protection Agency, Part VI, "Polychlorinated Biphenyls; Criteria Modification: Hearings," Federal Register, p. 31519 (May 31, 1979).

5. "EPA Seeks Comments on Decision to Test Proposed PCB Disposal Method," Environment Reporter, p. 666 (July 13, 1979).

APPENDIX A-24 ----- Phenol

PHENOL (MONOHYDROXYBENZENE) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-95-2

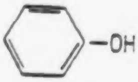
Synonyms: Carbolic acid; phenic acid; phenylic acid; oxybenzene; phenyl hydroxide; hydroxybenzene

Chemical Formula

Molecular Weight: 94.11

Molecular Formula: C_6H_6O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Solid colorless, acicular crystals or white cryst mass

Boiling Point: 181.9°C at 760 mm

Melting Point: 42.5 to 43°C

Density: 1.0576 at 20°C/4°C

Vapor Pressure: 0.530 mm at 25°C, 1 mm at 40°C

Vapor Density: 3.24

Solubility: Soluble (86.6 gm/l of H_2O), infinitely soluble in hot H_2O

Log Partition Coefficient (Octanol/H_2O): 1.48

Atmospheric Reactivity

Transformation Products: Reacts with oxidizing materials (forming a variety of products including benzenediols, benzenetriols, and diphenyls). Rapidly biodegraded to catechol, CH_2, CH_3 and-keto-adipate, cis, cis-muconate

Reactivity Toward OH·: 2 x butane

Reactivity Toward O_3: t 1/2 = 9.6 hr. 15% propylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

I. SOURCES

A. PRODUCTION

Phenol (C_6H_5OH) is currently produced in the United States synthetically by the cumene process and by the oxidation of toluene. The cumene process represents over 90% of the capacity for synthetic phenol. In the cumene process, cumene is oxidized with air to cumene hydroperoxide which is then decomposed by sulfuric acid hydrolysis to yield phenol and acetone. Toluene oxidation consists of oxidation of toluene to benzoic acid with subsequent oxidation of the benzoic acid to phenol. Kalama Chemical at its plant in Kalama, Washington, is the only synthetic producer that uses the toluene oxidation process. All others use the cumene process.

There are currently 11 producers of synthetic phenol in the United States. The locations of the plants and the 1978 capacity and estimated production levels for each plant are shown in Table 24-1.[1,2] In 1978 an estimated 2375 million lb of phenol was produced.

Phenol is also produced "naturally" from coal tar and petroleum fractions at the five locations shown in Table 24-2.[1] Natural phenol production for 1978 was estimated to have been 27 million lb.

B. USES

Phenol is a major chemical intermediate used to produce a variety of other chemicals and products. The largest end-use of phenol is for the manufacture of phenol-formaldehyde (phenolic) resins which are used primarily in plywood adhesives, insulation binders, and molding compounds. An estimated 1045 million lb of phenol was consumed for this end use. An estimated 405 million lb of phenol was used to manufacture Bisphenol-A which is used to make epoxy resins. Caprolactam production, which is a starting material for nylon manufacture, consumed 15% (355 million lb) of phenol production. Other uses of phenol include the manufacture of nonylphenol (2%), salicylic acid (2%), dodecyphenol (1%), and adipic acid (1%). Other miscellaneous uses consume an estimated 15% of phenol production. Exports in 1978 were estimated to consume 3% (71 million lb) of production. End-uses are summarized in Table 24-3.[1] Identifiable source locations of phenol end-users, excluding phenol resins, are shown in Table 24-4. Phenolic resin plant are so

Table 24-1. Phenol Producers (Synthetic Phenol)[a]

Company	Location	1978 Capacity (10^6 lb/yr)	1978 Production[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Allied Chemical[d]	Philadelphia, PA	600	453	40 00 24 75 04 07
Clark	Blue Island, IL	88	66	41 39 21/87 41 56
Dow	Freeport, TX	465	351	28 59 12/95 24 05
Georgia Pacific	Plaquemine, LA	265	200	30 15 00/91 11 00
Getty	El Dorado, KS	95	72	37 47 10/96 52 00
Kalama	Kalama, WA	75	57	46 00 54/122 51 05
Monsanto	Chocolate Bayou, TX	500	377	20 14 55/95 12 45
Shell	Deer Park, TX	500	377	29 42 57/95 07 28
Standard Oil of California	Richmond, CA	55	42	37 56 12/122 20 48
Union Carbide	Bound Brook, NJ	180	135	40 33 32/74 31 18
U.S. Steel	Haverhill, OH	325	245	38 34 52/82 49 36
Total		3148[c]	2375	

[a] See refs. 1 and 2.

[b] Total production distributed based on individual site capacity.

[c] Reichhold put a 150 $\bar{M}$ lb/yr plant on stand-by in the first quarter of 1978 at Tuscaloosa, AL.

[d] See ref. 8

Table 24-2. Phenol Producers (Natural Phenol)[a]

Company	Location	1978 Capacity[b] (10^6 lb/yr)	1978 Production[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Ferro Corporation	Sante Fe Springs, CA	12	5.4	33 56 30/118 04 18
Koppers	Follansbee, WV	12	5.4	40 23 10/80 35 07
Merichem	Houston, TX	12	5.4	29 45 36/95 10 48
Stimson Lumber	Anacortes, WA	12	5.4	48 28 31/122 32 48
U.S. Steel Corporation	Clairton, PA	12	5.4	40 18 15/79 52 43
Total		60	27	

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[a] See ref. 1.

[b] Total capacity and production distributed evenly over all five sites in the absence of capacity figures.

Table 24-3. Phenol End-Use 1978
(Synthetic and Natural Phenol)*

Source	Usage (10^6 lb/yr)	% Usage
Phenolic resins	1045	44
Bisphenol-A	405	17
Caprolactam	355	15
Nonylphenol	48	2
Salicylic acid	48	2
Dodecylphenol	24	1
Adipic acid	24	1
Miscellaneous	382	15
Exports	71	3
Total	2402	100

*See ref. 1.

Table 24-4. Phenol User Locations

Company	Location	1978 Production Capacity (lb/yr)	1978 Phenol Usage (lb/yr)	Geographic Coordinates Latitude/Longitude
		Bisphenol-A Producers[a]		
Dow	Freeport, TX	150	95	28 59 12/95 24 05
General Electric	Mount Vernon, IN	220	140	37 56 42/87 34 25
Shell	Deer Park, TX	150	95	29 42 55/95 07 34
U.S. Steel	Haverhill, OH	120	75	38 34 52/82 49 36
	Total	640	405	
		Caprolactam Producer[b]		
Allied	Hopewell, VA	400	355	37 22 13/77 18 08
	Total	400	355	
		Nonylphenol Producers[b]		
Borg Warner	Morgantown, WV	60	10	39 40 39/80 58 34
Exxon	Bayway, NJ	20	3	40 38 46/74 11 48
GAF	Calvert City, KY	5	1	37 02 50/88 21 12
	Linden, NJ	20	3	40 38 19/74 15 26
Jefferson	Port Neches, TX	35	6	29 57 45/93 56 00
Kalama	Kalama, WA	20	3	46 00 54/122 51 05
Monsanto	Kearney, NJ	40	6	40 46 12/74 09 08
Rohm and Haas	Deer Park, TX	10	2	29 43 30/95 06 15
	Philadelphia, PA	20	3	39 54 50/75 11 30
Schenectady	Rotterdam Junction, NY	20	3	42 47 22/73 43 12
	Oyster Creek, TX	50	8	29 58 21/95 20 38
	Total	300	48	
		Salicylic Acid Producers[c]		
Dow	Midland, MI	15	14	43 35 28/84 13 08
Monsanto	St. Louis, MO	20	18	38 34 37/90 11 42
Sterling Drug	Cincinnati, OH	8	7	39 05 15/84 33 09
Tenneco	Garfield, NJ	10	9	40 52 28/74 06 49
	Total	53	48	
		Dodecylphenol Producers[b]		
Borg Warner	Morgantown, WV	60	4	39 40 39/80 58 34
GAF	Calvert City, KY	5	1	37 02 05/88 21 12
Monsanto	Kearney, NJ	40	9	40 46 12/74 09 08
	Total	105	24	
		Adipic Acid Producer[b]		
Allied	Hopewell, VA	30	24	37 22 13/77 18 08
	Total	30	24	

[a] See ref. 3.

[b] See ref. 1.

[c] See ref. 4

numerous (total 125)[1] that they had to be tabulated by geographic region. They are shown in the emissions section of this report.

II. EMISSION ESTIMATES

A. PRODUCTION

Phenol emission estimates from both synthetic and natural phenol producers are tabulated in Table 24-5. Total phenol emissions from these sites are estimated to be 3,708,080 lb. Emission factors used to develop process, storage, and fugitive emission estimates (except where noted) are shown in Table 24-6. Emission factors derived for the cumene process were used for all producers in the absence of any site visit, state file, or other published data on toluene oxidation or natural phenol production. Process emissions originate primarily from catalytic columns and steaming column vents. Storage emissions represent the losses from both working and final storage tanks as well as loading and unloading losses. Fugitive emissions are those caused by leaks from plant equipment. Other associated emission components would include acetone, benzene, a-methyl styrene and cumene from the process, and toluene and benzene from the toluene oxidation process.

B. USES

Phenol emissions resulting from the production of phenol-formaldehyde resins (phenolic) were estimated to have been 522,200 lb in 1978. The total estimated emissions, the total number of phenolic resin plants, and the average emission rate per site are shown in Table 24-7.[7] Total emissions were estimated from the usage shown in Table 24-3 and the emission factors in Table 24-6. They were distributed by the total number of sites in each region.

Table 24-8 shows the emission estimates for all other identifiable phenol end-users.
Phenol emissions from the four Bisphenol-A plants were estimated to have been 202,500 lb in 1978.

Table 24-5. Phenol Emissions from Phenol Producers

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Allied[c]	Philadelphia, PA	23,000	172,000	12,740	207,740	2.99
Clark	Blue Island, IL	117,480	1,960	27,060	146,520	2.11
Dow	Freeport, TX	624,780	10,530	143,910	779,220	11.22
Georgia Pacific	Plaquemine, LA	356,000	6,000	82,000	444,000	6.39
Getty	El Dorado, KS	128,160	2,160	29,520	159,840	2.30
Kalama	Kalama, WA	101,460	1,710	23,370	126,540	1.82
Monsanto[d]	Chocolate Bayou, TX	8,419	142	19,390	10,500	0.15
Shell	Deer Park, TX	671,060	11,310	154,570	836,940	12.05
Standard Oil of California	Richmond, CA	74,760	1,260	17,220	93,240	1.34
Union Carbide	Bound Brook, NJ	240,300	4,050	55,350	299,700	4.31
U.S. Steel	Haverhill, OH	436,100	7,350	100,450	543,900	7.83
Ferro	Sante Fe Springs, CA	9,612	162	2,214	11,988	1.73
Koppers	Follansbee, WV	9,612	162	2,214	11,988	1.73
Merichem	Houston, TX	9,612	162	2,214	11,988	1.73
Stimson	Anacortes, WA	9,612	162	2,214	11,988	1.73
U.S. Steel	Clairton, PA	9,612	162	2,214	11,988	1.73
Total		2,829,579	219,302	659,199	3,708,080	

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[a] Based on the emission factors for phenol production shown in Table 6.

[b] Based on 8760 hr/yr operation.

[c] See ref. 8

[d] See ref. 10

Table 24-6. Phenol Production and End-Use Emission Factors

Source	Emission Factor lb Phenol Lost per lb Used (Produced)				
	Process	Storage	Fugitive	Total	Derivation[a]
Phenol production[e]	0.00178	0.00003	0.00041	0.00222	C[b]
Caprolactam	0.00130	0.00001	0.00013	0.00144	A[c]
Bisphenol A	0.00035	0.00003	0.00012	0.00050	C[b]
Nonylphenol[f]	0.00080	0.00001	0.00019	0.00100	C[b]
Salicylic Acid	0.00035	0.00001	0.00014	0.00050	C[b]
Dodecylphenol	0.00080	0.00001	0.00019	0.00100	D
Phenolic resins	0.00035	0.00002	0.00013	0.00050	D
Adipic acid	Phenol emissions are included with caprolactam production losses				
Miscellaneous				0.00068[d]	

[a] A - site visit data
B - state files
C - published data
D - Hydroscience estimate

[b] See ref. 5.

[c] See ref. 6.

[d] Based on a weighted average of all other phenol end-use emission factors.

[e] Does not apply to Allied Chemical, Philadelphia PA (ref. 8)

[f] The total emission factor for Exxon, Bayway, NJ is 0.0003 lbs of Phenol lost per lb used (ref. 9)

Table 24-7. Phenol Emissions from Phenolic Resin Producers by Region[a]

Region	Number of Sites	Phenol Emissions (lb/yr)[b]
New England	6	25,080
Middle Atlantic	26	108,680
East North Central	31	129,580
West North Central	5	20,900
South Atlantic	15	62,700
East South Central	6	25,080
West South Central	11	45,980
Mountain	1	4,180
Pacific	24	100,320
Total	125	522,500[c]

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[a] See ref. 7.

[b] Average emissions per site:

lb/yr		g/sec
2926	Process	0.042
167	Storage	0.002
1087	Fugitive	0.016
4180	Total	0.060

[c] Based on emission factors shown in Table 6.

Allied at Hopewell, Virginia, is the only producer of caprolactam derived from phenol. Adipic acid is considered a by-product of the caprolactam manufacture. Emissions of 511,200 lb phenol shown in Table 8 actually represent the total losses from Allied's facility in the production of both products.

Phenol emissions from nonylphenol and dodecylphenol are estimated to have been 41,700 and 24,000 lb respectively. The same emission factor was used for both products since they are made by the same producers in the same equipment.

Salicylic acid, the main ingredient in aspirin production, had estimated phenol emissions of 24,000 lb in 1978 at the four producing locations listed.

The other miscellaneous uses of phenol are very small but numerous. Specific industry and site identification was not possible, so point source or regional locations could not be determined.

Total estimated emissions of 259,760 lb for miscellaneous uses of phenol were made by using a weighted average emission factor of 0.00068 derived from all other phenol end-uses. Emissions from exports were assumed to be negligible.

Vent parameter data for phenol production and end-uses are tablulated in Table 24-9.

Total nationwide emissions of phenol in 1978 from all sources are estimated to have been 6,124,480lb. A tabulation of the losses is shown in Table 24-10.

Table 24-8. Phenol Emissions from End-Users

Company	Location	Phenol Emissions[a] Process	Storage	Fugitive	Total (lb/yr)	Total (g/sec)[b]
		Bisphenol-A Producers				
Dow	Freeport, TX	33,250	2,850	11,400	47,500	0.68
General Electric	Mount Vernon, IN	49,000	4,200	16,800	70,000	1.01
Shell	Deer Park, TX	33,250	2,850	11,400	47,500	0.68
U.S. Steel	Haverhill, OH	26,250	2,250	9,000	37,500	0.54
	Total	141,750	12,150	48,600	202,500	
		Caprolactam Producer				
Allied	Hopewell, VA	461,500	3,550	46,150	511,200	7.36
	Total	461,500	3,550	46,150	511,200	
		Nonylphenol Producers				
Borg Warner	Morgantown, NY	8,000	100	1,900	10,000	0.144
Exxon	Bayway, NJ	450	28	522	1,000	0.014
GAF	Calvert City, KY	800	10	190	1,000	0.014
	Linden, NJ	2,400	30	570	3,000	0.043
Jefferson	Port Neches, TX	4,800	60	1,140	6,000	0.086
Kalama	Kalama, WA	2,400	30	570	3,000	0.043
Monsanto	Kearncy, NJ	1,360	17	323	1,700	0.024

Table 24-8 (continued)

Company	Location	Phenol Emissions[a]				
		Process	Storage	Fugitive	Total (lb/yr)	Total (g/sec)[b]
		Nonylphenol Producers (Continued)				
Rohm and Haas	Deer Park, TX	1,600	20	380	2,000	0.029
	Philadephia, PA	2,400	30	570	3,000	0.043
Schenectady	Rotterdam Junction, NY	2,400	30	570	3,000	0.043
	Oyster Creek, TX	6,400	80	1,520	8,000	0.115
	Total	33,010	435	8,255	41,700	
		Salicylic Acid Producers				
Dow	Midland, MI	4,900	140	1,960	7,000	0.101
Monsanto	St. Louis, MO	6,300	180	2,520	9,000	0.130
Sterling Drug	Cincinnati, OH	2,450	70	980	3,500	0.050
Tenneco	Garfield, NJ	3,150	90	1,260	4,500	0.065
	Total	16,800	480	6,720	24,000	
		Dodecylphenol Producers				
Borg Warner	Morgantown, WV	11,200	140	2,660	14,000	0.202
GAF	Calvert City, KY	800	10	190	1,000	0.014
Monsanto	Kearney, NJ	7,200	90	1,710	9,000	0.130
	Total	19,200	240	4,560	24,000	
		Adipic Acid Producer				
Allied	Hopewell, VA	Emissions are included in caprolactam production losses				

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[a] Based on emission factors shown in Table 6.

[b] Based on 8760 hr/yr operation.

Table 24-9. Phenol Vent Parameters for Production and End-use Facilities

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temp. (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Production						
Process	3	75	0.4	125	2	
Storage	10	25	0.33	150		
Fugitive						300 X 1000
Phenolic resins						
Process	1	60	0.33	150	20	
Storage	2	24	0.17	150		
Fugitive						100 X 100
Bisphenol A						
Process	2	40	0.5	100	24	
Storage	6	24	0.25	150		
Fugitive						300 X 300
Caprolactam/adipic acid						
Process	2	60	1.0	90	500	
Storage	8	24	0.17	150		
Fugitive						100 X 200
Nonyl/dodecylphenol						
Process	2	60	0.5	160	60	
Storage	3	20	0.17	150		
Fugitive						100 X 200
Salicylic acid						
Process	1	55	0.5	120	5	
Storage	3	20	0.17	150		
Fugitive						100 X 200

Building cross-section	Producers	100 m^2
	Resins	50 m^2
	Bisphenol A	50 m^2
	Caprolactam	200 m^2
	Nonyl/dodecybenzenes	25 m^2
	Salicylic acid	50 m^2

Table 24-10. Phenol Nationwide Emissions

Source	Nationwide Emissions (lb/yr)
Production	3,708,080
Phenolic resins	522,500
Bisphenol-A	202,500
Caprolactam[a]	511,200
Nonylphenol	41,700
Salicylic acid	24,000
Dodecylphenol	24,000
Miscellaneous	259,760
Export	0
Total	5,293,740

[a] Includes emissions from adipic acid manufacture.

[b] Based on an emission factor of 0.00068 lb phenol lost per lb used. Derived from a weighted average of all other phenol uses.

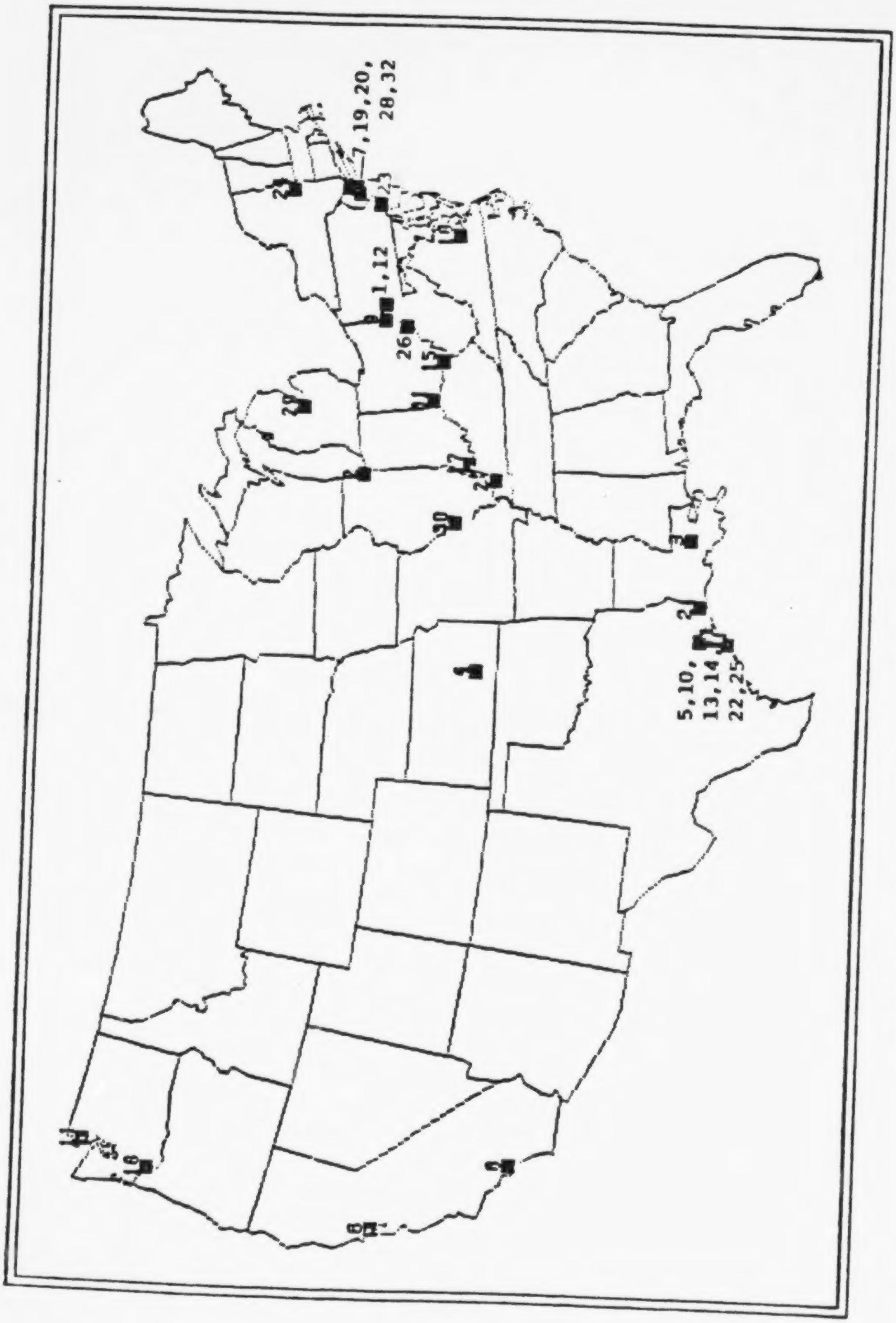
7,19,20,
28,32
1,12
26
5,10,
13,14
22,25
2
3
4

FIGURE 24-1. SPECIFIC POINT SOURCES OF PHENOL EMISSIONS

Table 24-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PHENOL

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ALLIED	PHILADELPHIA, PA	40 00 24	075 04 07	13739	1	1	.033105	2.479071	.183631
2	CLARK	BLUE ISLAND, IL	41 39 21	087 41 56	14855	1	1	1.691686	.028539.	.389650
3	GEORGIA PACIFIC	PLAQUEMINE, LA	30 15 00	091 11 00	13970	1	1	5.126427	.086251	1.180809
4	GETTY	EL DORADO, KS	37 47 10	096 52 00	13969	1	1	1.845510	.031076	.425101
5	MONSANTO	CHOCOLATE BAYOU, TX	29 14 55	095 12 45	12906	1	1	.121093	.002042	.027889
6	STANDARD	RICHMOND, CA	37 56 12	122 20 48	12906	1	1	1.076579	.018075	.247971
7.	UNION CARBIDE	BOUND BROOK, NJ	40 33 32	074 31 18	94741	1	1	3.460331	.058346	.797057
8.	FERRO	SANTE FE SPGS., CA	33 56 30	118 04 18	93106	1	1	.138413	.002315	.031868
9.	KOPPERS	FOLLANSBEE, WV	40 23 10	080 35 07	14762	1	1	.138413	.002315	.031868
10.	MERICHEM	HOUSTON, TX	29 45 36	095 10 48	12906	1	1	.138413	.002315	.031868
11.	STIMSON	ANACORTES, WA	48 28 31	122 32 48	24217	1	1	.138413	.002315	.031868
12.	US STEEL	CLAIRTON, PA	40 18 15	079 52 43	14762	1	1	.138413	.002315	.031868
13	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	2	1	8.996860	.151573	2.072298
14	SHELL	DEER PARK, TX	29 43 30	095 06 15	12906	2	2	.478818	.041096	.164162
							1	9.663241	.162986	2.225805
15	US STEEL	HAVERHILL, OH	38 34 52	082 49 36	13866	2	2	.478818	.041096	.164162
							1	6.272577	.105720	1.444793
16	KALAMA	KALAMA, WA	46 00 54	122 51 05	24229	3	2	.377568	.032516	.129439
							1	1.460997	.024734	.336536
17	GEN ELECTRIC	MOUNT VERNON, IN	37 56 42	087 34 25	93817	4	4	.034564	.000476	.008213
							2	.705606	.060502	.241914
18	ALLIED	HOPEWELL, VA	37 22 13	077 18 08	13740	5	3	6.645611	.051243	.664574

Table 24-11. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PHENOL (Concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
19	EXXON	BAYWAY, NJ	40 38 46	074 11 48	94741	6	4	.006469	.000412	.007515
20	GAF	LINDEN, NJ	40 38 19	074 15 26	94741	6	4	.034564	.000412	.008213
21	JEFFERSON	PORT NECHES, TX	29 57 45	093 56 00	12917	6	4	.069127	.000856	.016426
22	ROHMAND HAAS	DEER PARK,TX	29 43 30	095 06 15	12906	6	4	.023085	.000285	.005486
23	ROHMAND HAAS	PHILADELPHIA, PA	39 54 50	075 11 30	13739	6	4	.034564	.000412	.008213
24	SCHENECTADY	R JUNCTION, NY	42 47 22	073 43 12	14735	6	4	.034564	.000412	.008213
25	SCHENECTADY	OYSTER CREEK, TX	29 58 21	095 20 38	12960	6	4	.092149	.001142	.021880
26	BORG WARNER	MORGANTOWN, PA	39 40 39	080 58 34	13736	7	4	.115170	.001427	.027366
27	GAF	CALVERT CITY, KY	37 02 50	088 21 12	03816	7	6 4	.161276 .011542	.001998 .000190	.038305 .002727
28	MONSANTO	KEARNEY, NJ	40 46 12	074 09 08	94741	7	6 4	.011542 .019451	.000190 .000245	.002727 .004646
29	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	8	6 5	.103691 .070654	.001332 .001998	.024639 .028223
30	MONSANTO	ST. LOUIS, MO	38 34 37	090 11 42	13994	8	5	.090722	.002568	.000349
31	STERLING DRUG	CINCINNATI, OH	39 05 15	084 33 09	13840	8	5	.035293	.001046	.014111
32	TENNECO	GARFIELD, NJ	40 52 28	074 06 47	94741	8	5	.045345	.001332	.018138

TABLE 24-11 (Concluded)

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* Plant Types:
Type 1: Plant produces phenol
Type 2: Plant produces phenol and Bisphenol-A
Type 3: Plant produces phenol and nonylphenol
Type 4: Plant produces Bisphenol-A
Type 5: Plant produces caprolactam and adipic acid
Type 6: Plant produces nonylphenol
Type 7: Plant produces nonylphenol and dodecylphenol
Type 8: Plant produces salicylic acid

† Source Types:
Type 1: Phenol production
Type 2: Bisphenol-A production
Type 3: Caprolactam/adipic acid production
Type 4: Nonylphenol production
Type 5: Salicylic acid production
Type 6: Dodecylphenol production

TABLE 24-12. EXPOSURE AND DOSAGE OF PHENOL RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
100	0	0
50	0	3
25	75	2,150
10	607	10,400
5	3,733	31,200
2.5	14,896	686,000
1	79,518	167,000
0.5	247,866	282,000
0.25	612,488	407,000
0.1	1,847,851	592,000
0.05	3,751,128	725,000
0.025	6,318,109	817,000
0.01	8,859,612	860,000
0.005	10,780,296	874,000
0.0025	14,385,766	886,000
0.001	23,119,700	900,000
4.58×10^{-5}*	35,736,282	907,000

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* The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 24-13. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF PHENOL (PHENOIC RESINS PRODUCTION)*

Region	Emissions/Site (gm/sec)	Number of Sites
New England	0.0602	6
Middle Atlantic	0.0602	26
East North Central	0.0602	31
West North Central	0.0602	5
South Atlantic	0.0602	15
East South Central	0.0602	6
West South Central	0.0602	11
Mountain	0.0602	1
Pacific	0.0602	24

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* Emissions parameters:

Vent height: 13 m
Building cross section: 50 m^2
Vent diameter: 0.085 m
Vent velocity: 4.2 m/sec
Vent temperature: 339° K

TABLE 24-14. EXPOSURE AND DOSAGE RESULTING FROM GENERAL POINT SOURCES OF PHENOL (PHENOLIC RESINS PRODUCTION)

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)	Dosage [10^3 ($\mu g/m^3$) • persons]
2.5	2.1	6.7
1	19	31
0.5	63	62
0.25	173	99
0.1	539	153
0.05	--	218
0.025	--	370
0.01	--	447
0	--	725

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 24-15. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF PHENOL

Parameter	Value
Daytime decay rate (K_d)	2.95×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	1.5×10^{-6} sec^{-1}
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	3.74 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 24-16. PHENOL EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level (µg/m³)	Population (person)	Dosage (µg/m³/person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.010000	505140	10017.9	0.	100.0	0.	100.0	0.	0.
.005000	9149730	74338.2	0.	100.0	0.	100.0	0.	0.
.002500	27656703	134272.7	0.	100.0	0.	100.0	0.	0.
.001000	87809142	217937.4	0.	100.0	0.	97.6	1.0	1.4
.000500	135741991	253535.3	0.	100.0	0.	94.4	2.5	3.2
0.	158679135	261345.4	0.	100.0	0.	92.7	2.7	4.6

TABLE 24-17. EXPOSURE AND DOSAGE SUMMARY OF PHENOL

	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
Concentration Level (ug/m^3)	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	0	0	0	0	0	0	0	0
50	0	0	0	0	3	0	0	3
25	75	0	0	75	2,150	0	0	2,150
10	607	0	0	607	10,400	0	0	10,400
5	3,733	0	0	3,733	31,200	0	0	31,200
2.5	14,896	2,100	0	16,996	68,600	4,030	0	72,630
1.	79,518	19,000	0	98,518	167,000	28,600	0	195,600
0.5	247,866	63,000	0	310,866	282,000	55,300	0	337,300
0.25	612,488	173,000	0	785,488	407,000	82,100	0	489,100
0.1	1,847,851	539,000	0	2,386,851	592,000	129,000	0	721,000
0.05	3,751,128	--	0	--	725,000	177,000	0	902,000
0.025	6,318,109	--	0	--	817,000	225,000	0	1,042,000
0.01	8,859,612	--	505,140	--	860,000	294,000	10,017	1,164,017
0.005	10,780,296	--	9,149,730	--	874,000	--	74,338	--
0.0025	14,385,766	--	27,656,703	--	886,000	--	134,272	--
0.001	23,119,700	--	87,809,142	--	900,000	--	217,937	--
0.0005	29,934,481	--	135,741,991	--	905,000	--	253,535	--
0	35,736,282	--	158,679,135	--	907,000	555,000	261,343	1,723,343

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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4. "Chemical Products Synopsis on Salicylic Acid," Mannsville Chemical Products, Mannsville, NY (December 1977).

5. Special Project Report "Petrochemical Plant Site," Monsanto Research Corporation, April 15, 1976.

6. Trip Report, Emission Control Options for the Synthetic Organic Chemicals Manufacturing Industry, Allied Chemical Corporation, Hopewell, VA, plant visit by Hydroscience, Inc., February 21, 1978.

7. "Phenolic Resins," p. 580.0933B--O, Chemical Economics Handbook, Stanford Research Institute, Menlo Park, CA (May 1978).

8. Allied Chemical, (J. D. Alcorta), Personal communication in response to the first draft of this report (June 1981).

9. Exxon Chemical Americas (J. P. Thorn), Personal communication in response to the first draft of this report (August 1981).

10. Monsanto Company (C.D. Malloch) personal communication in response to publication of the second draft of this report (July 1982).

APPENDIX A-25 ----- Phosgene

PHOSGENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-44-5

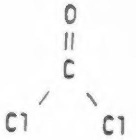
Synonyms: Carbonoxychloride; Carbonylchloride; CG; Carbonic Dichloride; Chloroformyl Chloride

Chemical Formula

Molecular Weight: 98.92

Molecular Formula: $COCl_2$

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Gas (or volatile liquid) - colorless; highly toxic, suffocating odor

Boiling Point: 7.56°C at 760 mm

Melting Point: -118°C

Density: 19°C/4°C

Vapor Pressure: 1428 mm at 25°C

Vapor Density: 3.4

Solubility: Decomposes in H_2O

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products: Decomposes in H_2O to form HCl

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors:

Formation Reactivity:

I. PRODUCTION

A. PRODUCTION SITES

Phosgene ($COCl_2$) is made by reacting carbon monoxide and chlorine in the presence of a catalyst, usually activated carbon. The hot product gases are put through a condenser where liquid phosgene is removed. Additional phosgene is scrubbed from the system with a hydrocarbon solvent. In most cases the phosgene is used as it is made, and the solvent in the scrubber may be the same solvent in which subsequent processing takes place.

There are currently 17 phosgene producers in the United States. The locations of the plants and the 1978 capacity and estimated production levels for each plant are shown in Table 25-1. In 1978, an estimated 1243.4 million lb of phosgene was produced.

Virtually all phosgene produced is used captively. The Chemetron site at Laporte, Texas, and the VanDeMark site at Lockport, New York are believed to be the only producers of phosgene for the merchant market.

B. END-USE DISTRIBUTION

Table 25-2 shows the end-use distribution for phosgene. Approximately 60% of the phosgene produced is used to make toluene diisocyanate (TDI), and 25% is used to make polymeric isocyanates. Phosgene is also used in the manufacture of polycarbonates and other miscellaneous products.

C. EMISSION ESTIMATES

Phosgene emissions from phosgene producers are shown in Table 25-3. Total estimated phosgene emissions from the 18 sites that produce phosgene were 190,960 lb/yr in 1978. Emission factors used to develop process vent storage and fugitive emission estimates are also shown in Table 25-3. There were no proven vent or storage emissions. Fugitive emissions from plant equipment accounted for the total phosgene emissions. Emissions estimates are based on a plant operation schedule of 24 hr/day, 7 days/week, 52 weeks/yr. Vent stack data, where available, were reported in Table 25-3. In this case limited data were available, and data from one site were used for all the sites.

Table 25-1. Phosgene Producers*

Company	Location	1978 Capacity (10^6 lb/yr)	1978 Production (10^6 lb/yr)	Geographical Location Latitude/Longitude
Allied Chemical	Moundsville, WV	100	76	39 54 24/80 47 51
BASF Wyandotte	Geismar, LA	55	41.8	30 11 34/91 00 42
Chemtron	LaPorte, TX	80	60.8	29 39 20/95 02 18
Dow Chemical	Freeport, TX	130	98.8	28 59 12/95 24 05
Du Pont	Deepwater, NJ	135	102.6	39 41 25/75 30 35
General Electric	Mt. Vernon, IN	60	45.6	37 56 42/87 54 25
Jefferson	Port Neches, TX	30	22.8	30 18 50/95 23 06
Minerec	Baltimore, MD	8	6.1	39 14 11/76 34 41
Mobay Chemical	Baytown, TX	250	190	29 45 30/94 54 25
	New Martinsville, WV	250	190	39 43 35/80 49 43
Olin	Ashtabula, OH	50	38	50 53 46/80 43 22
	Lake Charles, LA	120	91.2	30 13 55/93 15 57
PPG	Barberton, OH	5	3.8	41 00 37/81 36 29
Rubicon Chemicals	Geismar, LA	130	98.8	30 12 00/91 00 30
Stauffer Chemicals	Cold Creek, AL	25	19	30 58 30/88 01 16
Upjohn	LaPorte, TX	200	152	29 42 26/95 04 29
Van De Mark	Lockport, NY	8	6.1	43 11 08/78 42 40
Total		1,636	1,243.4	

*See ref. 1 and 2.

Table 25-2. Phosgene End-Use Distribution*

Source	Usage (10^6 lbs/yr)	% Usage
Toluene diisocyanates (TDI)	758.9	60
Polymeric isocyanates (MDI)	339.5	25
Polycarbonates	67.8	5
Miscellaneous	58.4	10
Total	1243.4	100

*See Reference 1.

Table 25-3. Phosgene Emissions from Phosgene Producers[a]

Company	Location	Total Emissions[b] (lb/yr)	Total Emissions[b] (g/sec)[c]
Allied Chemical	Moundsville, WV	4,341	0.063
BASF Wyandotte	Geismar, LA	276	0.004
Chemetron	LaPorte, TX	10,944	0.158
Dow	Freeport, TX	17,784	0.256
Du Pont	Deepwater, NJ	18,468	0.266
General Electric	Mt. Vernon, IN	8,208	0.118
Jefferson	Port Neches, TX	4,104	0.059
Minerec	Baltimore, MD	1,098	0.016
Mobay	Baytown, TX	34,200	0.492
	New Martinsville, WV	34,200	0.492
Olin	Ashtabula, OH	6,840	0.098
	Lake Charles, LA	154	0.394
PPG	Barberton, OH	684	0.010
Rubicon	Geismar, LA	17,784	0.256
Stauffer	Cold Creek, AL	3,420	0.049
Upjohn	Laporte, TX	27,360	0.394
Van De Mark	Lockport, NY	1,098	0.016
Total		190,960	2.749

[a] See ref 4.

[b] Emission factor phosgene (lb phosgene lost/lb phosgene produced)

Process	0
Storage	0
Fugitive	0.00018
	0.00018

fugitive emissions are distributed over a 300 X 300 ft area
Building cross-section - 200 m^2

[c] 8760 operating hours per year i.e. 24 hr/day, 7 days/wk, 52 wk/yr.

Process and storage emissions are negligible. The only emissions noted from production facilities are from fugitive sources; therefore, no process or storage vent parameter data are given.

II. USERS

A. USER SITES

Table 25-4 presents the phosgene users who manufacture toluene diisocyanate (TDI). There are 9 sites which used an estimated total of 758.9 million lb of phosgene in 1978.

Table 25-5 presents the phosgene users who manufacture polymeric isocyanates (MDI). There are 4 sites which used an estimated total of 339.5 million lb of phosgene in 1978.

B. EMISSION ESTIMATES

Table 25-6 presents the phosgene emissions from phosgene users that produce TDI. Estimated total emissions from these sites in 1978 were 4998 lb. Table 25-7 presents the phosgene emissions from phosgene users that produce MDI. Estimated total emissions from these sites in 1978 were 2140 lb.

III. TOTAL EMISSIONS

Table 25-8 presents a summary of the total phosgene emissions for all the production and user sites. A number of the plants produce phosgene for captive use in producing TDI and MDI.

Table 25-9 presents a summary of the phosgene usage and sources of phosgene emissions for production and various uses. Total nationwide emissions from producers and users for 1978 are estimated to have been 199,438 lb.

Table 25-4. Phosgene Users[a]
[Manufacturers of Toluene Diisocyanate (TDI)]

Company	Location	1978 TDI Capacity (10^6 lb/yr)	1978 Phosgene Use[b] (10^6 lb/yr)	Geographical Location Latitude/Longitude
Allied Chemical	Moundsville, WV	80	80.9[c]	39 54 39/80 44 49
BASF Wyandotte	Geismar, LA	100	101.2[c]	30 11 34/91 00 42
Dow Chemical	Freeport, TX	100	101.2[c]	28 59 12/95 24 05
DuPont	Deepwater, NJ	70	70.8	39 41 25/75 30 35
Mobay Chem. Corp.	Baytown, TX	130	131.5	29 45 30/94 54 25
Mobay Chem. Corp.	New Martinsville, WV	100	101.2	39 44 50/80 50 50
Olin Corp.	Ashtabula, OH	30	30.4	41 53 07/80 45 50
Olin Corp.	Lake Charles, LA	100	101.2[c]	30 13 55/93 15 57
Rubicon Chems. Inc.	Geismar, LA	40	40.5	30 12 00/91 11 30
	Total	750	758.9	

---

[a] See References 2, 3, and 4.

[b] Based on 60% of phosgene produced that is used to make TDI (see Reference 1).
Phosgene used = $\frac{\text{TDI capacity}}{805 \times 10^6 \text{ lb/yr}} \times .60$ (1357.4×10^6 lb/yr phosgene produced).

[c] Phosgene use exceeds phosgene produced at same plant.

Table 25-5. Phosgene Users[a]
(Manufacturers of Polymeric Isocyanates)

Company	Location	1978 Capacity (10^6 lbs/yr) MDI	1978 Phosgene[b] Use (10^6 lb/yr)	Geographical Location Latitude/Longitude
Mobay Chem. Corp.	Baytown, TX	110	81.25	29 45 30/94 54 25
Mobay Chem. Corp.	New Martinsville, WV	50	36.9	39 44 50/80 50 50
Rubicon Chemicals	Geismar, LA	50	36.9	30 12 00/91 00 30
Upjohn	LaPorte, TX	250	184.4	29 42 26/95 04 29
	Total	460	339.5	

[a] See Reference 4.

[b] Based on 25% of phosgene produced that is used to make MDI (see Reference 1).

Phosgene used = $\frac{\text{MDI Capacity}}{460 \times 10^6 \text{ lb/yr}} \times .25\ (1357.4 \times 10^6$ lb/yr phosgene produced).

Table 25-6. Phosgene Emissions from Phosgene Users for TDI Production[a]

Company	Location	Process Vents Emissions (lb/yr)	Process Vents Emissions (g/sec)	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)	Total Emissions (lb/yr)	Total Emissions (g/sec)
Allied Chemical[b]	Moundsville, WV	169	0.002	Nil	Nil	169	0.002
BASF Wyandotte[b]	Geismar, LA	24	-	Nil	Nil	24	-
Dow	Freeport, TX	666	0.01	Nil	Nil	666	0.01
Du Pont	Deepwater, NJ	466	0.007	Nil	Nil	466	0.007
Mobay	Baytown, TX	868	0.012	Nil	Nil	868	0.012
Olin[b]	New Martinsville, WV	666	0.01	Nil	Nil	666	0.01
	Ashtabula, OH	200	0.003	Nil	Nil	200	0.003
	Lake Charles, LA	6	-	Nil	Nil	6	-
Rubicon	Geismar, LA	266	0.004	Nil	Nil	266	0.004
Total						4,998	0.074

---

[a] Based on the following emission factors (lb phosgene emitted per lb produced):

Process	0.000006	B - (derived from state air emission files)
Storage	Nil	B - (derived from state air emission files)
Fugitive	Nil	B - (derived from state air emission files)
	0.000006	

Average process vent stack parameters for all locations are:

27.1 m - stack height
0.27 m - stack diameter
11.8 m/sec - stack velocity
43.5°C - stack temperature

Building cross-section - 200 m^2.

[b] Based on assumed distribution, see ref 9-11

Table 25-7. Phosgene Emissions from Phosgene Users for MDI Production[a]

Company	Location	Process Vents Emissions (lb/yr)	Process Vents Emissions (g/sec)	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)	Total Emissions (lb/yr)	Total Emissions (g/sec)
Mcbay	Baytown, TX	480	0.007	Nil	Nil	480	0.007
	New Martinsville, WV	220	0.003	Nil	Nil	220	0.003
Rubicon	Geismar, LA	220	0.003	Nil	Nil	220	0.003
Upjohn	LaPorte, TX	1220	0.018	Nil	Nil	1220	0.018
Total						2140	0.031

[a] Based on the following emission factors (lb phosgene emitted per lb produced):

Process	0.0000066	B - (derived from state air emission files)
Storage	0	B - (derived from state air emission files)
Fugitive	Nil	B - (derived from state air emission files)
	0.0000066	

Average process vent stack parameters for all locations are:

27.1 m - stack height
0.27 m - stack diameter
11.8 m/sec - stack velocity
43.5°C - stack temperature

Building cross-section - 200 m^2.

Table 25-8. Total Phosgene Emissions from Producer and Users[d]

Company	Location	Phosgene Emissions (lb/yr)	Phosgene Emissions (cm/sec)
Allied Chemical[a]	Moundsville, WV	4,510	0.065
BASF Wyandotte[a]	Geismar, LA	300	0.004
Chemetron	LaPorte, TX	10,944	0.153
Dow	Freeport, TX	18,450	0.266
DuPont	Deepwater, NJ	18,934	0.273
General Electric	Mt. Vernon, IA	8,208	0.118
Jefferson	Port Neches, TX	4,104	0.059
Minerec	Baltimore, MD	1,098	0.016
Mobay	Baytown, TX	35,548	0.511
Mobay	New Martinsville, WV	35,036	0.505
Olin	Ashtabula, OH	7,040	0.101
Olin[a]	Lake Charles, LA	160	0.002
PPG	Barberton, OH	684	0.01
Rubicon	Geismar, LA	18,270	0.263
Stauffer	Cold Creek, AL	3,420	0.049
Upjohn	LaPorte, TX	28,520	0.412
Van Demark	Lockport, NY	1,098	0.016
	Total	196,434	2.828

[a] See ref. 9

[b] See ref. 10

[c] See ref. 11

[d] Union Carbide at S. Charleston, WV No longer emitts phosgene ref. 12.

Table 25-9. Sources of Phosgene Emissions

Source	Production/ Usage (10^6 lb/hr)	% Usage	Total Emissions (lb/yr)	Total Emissions (gm/sec)
Producers	1243.4	-	190,960	2.749
Users:				
Toluene diisocyanate	758.9	60	4,998	0.074
Polymeric isocyanates	339.5	25	2,140	0.031
Polycarbonates	67.8	5	447*	0.006
Miscellaneous	58.4	10	893*	0.012
Total	1243.4	100	199,438	2.874

*Based on emission factor for toluene diisocyanate (TDI).

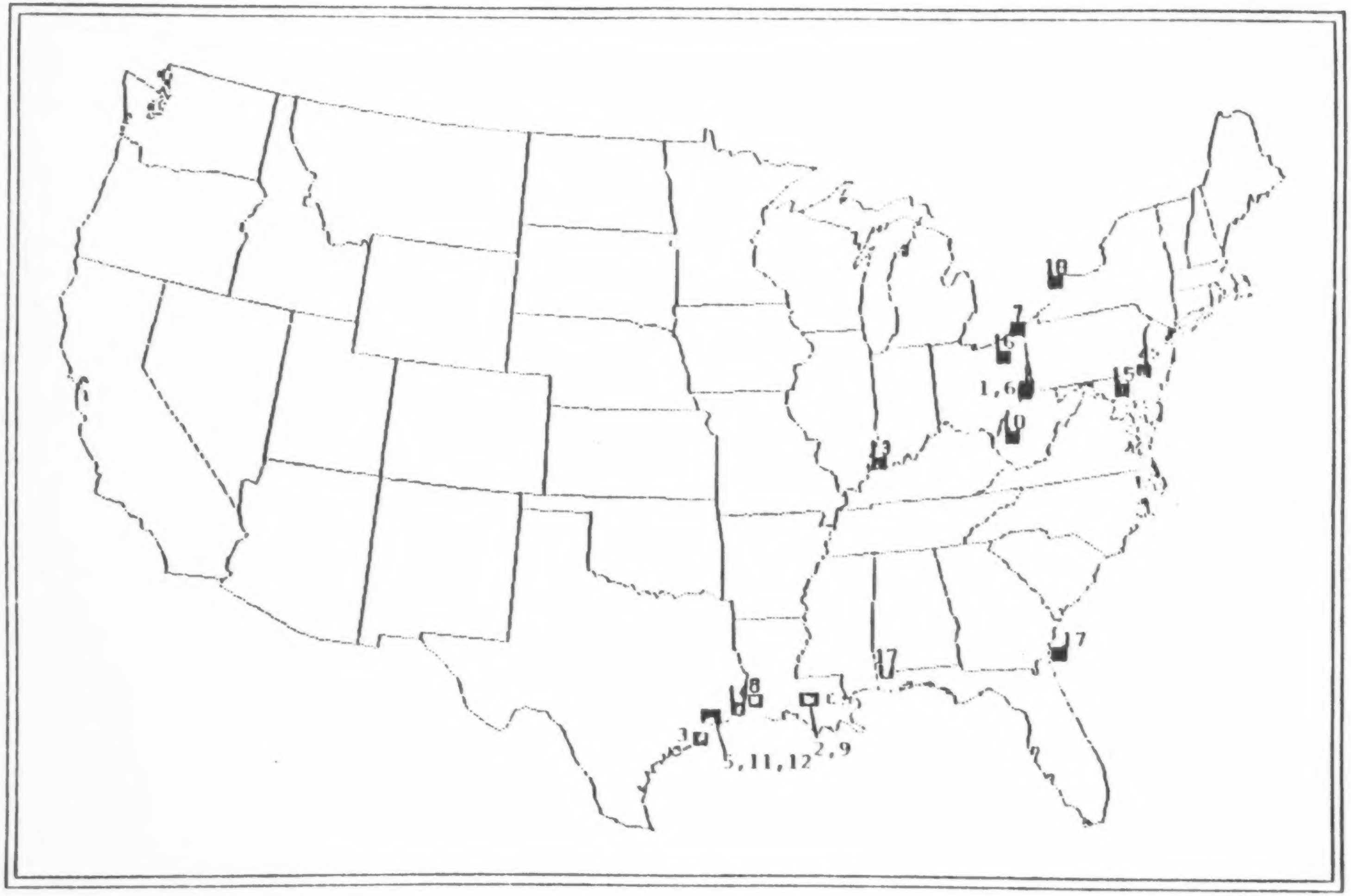

18
7
16
1,6
10
13
15
4
17
7
8
3
5,11,12
2,9

FIGURE 25-1. SPECIFIC POINT SOURCES OF PHOSGENE EMISSIONS

Table 25-10. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PHOSGENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ALLIED CHEMICAL	MOUNDSVILLE, WV	39 54 39	080 44 49	13736	1	1	.002442	0.	.062437
2	BASF WYANDOTTE	GEISMAR, LA	30 11 34	091 00 42	13970	1	1	.000349	0.	.003964
3	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	.256089	0.	.009576
4	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	1	1	.006722	0.	.265950
5	MOBAY	BAYTOWN, TX	29 45 30	094 54 25	12906	1	1	.019502	0.	.492485
6	MOBAY	NEW MARTINSVILLE,WV	39 44 50	080 50 50	13736	1	1	.492485	0.	.012747
7	OLIN	ASHTABULA, OH	41 53 07	080 45 50	14843	1	1	.002886	0.	.098491
8	OLIN	LAKE CHARLES, LA	30 13 55	093 15 57	03937	1	1	.000095	0.	.002220
9	RUBICON	GEISMAR, LA	30 12 00	091 11 30	12958	1	1	.007008	0.	.256088
10	UPJOHN	LAPORTE, TX	29 42 26	095 04 29	12906	1	1	.017567	0.	.393994
11	CHEMETRON	LAPORTE, TX	29 39 20	095 02 18	12906	2	1	0.	0.	.151890
12	GEN ELECTRIC	MT VERMON, IN	37 56 42	087 34 25	93817	2	1	0.	0.	.118182
13	JEFFERSON	PORT NECHES, TX	29 57 45	093 56 00	12917	2	1	0.	0.	.059107
14	MINEREC	BALTIMORE, MD	39 14 11	076 34 41	13701	2	1	0.	0.	.015823
15	PPG	BARBERTON, OH	41 00 37	081 36 29	14895	2	1	0.	0.	.009323
16	STAUFFER	COLD CREEK, AL	30 58 30	088 01 16	93841	2	1	0.	0.	.049245
17	VANDEMARK	LOCKPORT, NY	43 11 08	078 42 40	14747	2	1	0.	0.	.015823

TABLE 25-10 (Concluded)

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* Plant Types:

Type 1: Plant produces and consumes phosgene

Type 2: Plant produces phosgene

† Source Types:

Type 1: Phosgene production/consumption processes

TABLE 25-11. EXPOSURE AND DOSAGE OF PHOSGENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
10	1	10
5	8	57
2.5	42	167
1	185	379
0.5	454	564
0.25	1,580	962
0.1	12,568	2,600
0.05	42,880	4,470
0.025	122,705	7,230
0.01	435,912	11,800
0.005	981,804	15,600
0.0025	1,625,886	17,900
7.54×10^{-6}*	4,454,739	19,500

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* The lowest annual average concentration occurring within 20 km of the specific point source.

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11. Olin Chemicals Group, (V. M. Norwood), Personal communication in response to publication of the first draft of this report (November 1980).
12. Union Carbide Corporation, (R. L. Foster), Personal communcation in response to publication of the first draft of this report (September 1980).

APPENDIX A-26 ----- Propylene Oxide

PROPYLENE OXIDE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 75-56-9

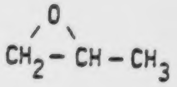
Synonyms: Propene Oxide; Methyl Oxirane; 1, 2 Epoxy Propane; Epoxypropane; Methy Ethylene Oxide; Propene Oxide; Propyleneoxide; 1, 2-Propylene Oxide

Chemical Formula

Molecular Weight: 58.08

Molecular Formula: C_3H_6O

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid-colorless, ethereal, extremely flammable

Boiling Point: 33.9°C at 760 mm

Melting Point: -104.4°C

Density: 0.8394 at 20°C/4°C

Vapor Pressure: 596 mm at 25°C

Vapor Density: 20

Solubility: Soluble (650 gm/l. of H_2O)

Log Partition Coefficient (Octanol/H_2O):

Atmospheric Reactivity

Transformation Products:

Reactivity Toward OH·:

Reactivity Toward O_3:

Reactivity Toward Photolysis:

Major Atmospheric Precursors:

Formation Reactivity:

I. SOURCES

A. PRODUCTION

Propylene oxide (C_3H_6O) is currently produced in the United States by chlorohydration or peroxidation of propylene. (Peroxidation is the direct oxidation of propylene.[1]) The chlorohydration of propylene oxide is similar to ethylene oxide manufacture via chlorohydrin. Many ethylene oxide plants have been converted to chlorohydrin PO plants. The basic raw materials for the chlorohydrin process are propylene, chlorine, and caustic. In the process propylene and hypochlorous acid are reacted to yield propylene chlorohydrin. The chlorohydrin is then treated with slaked lime or caustic to yield propylene oxide. Propylene dichloride is the major by-product.

There are currently seven producers of propylene oxide in the United States. The locations of the plants and the 1978 capacity and estimated production levels for each plant are shown in Table 26-1.[1,2] The two Oxirane Plants use the peroxidation process. All other sites produce propylene oxide by the chlorohydrin process. In 1978 an estimated 2000 million lb of propylene oxide was produced.

B. USES

Table 26-2[1,2] shows the distribution of end-uses of propylene oxide. The largest end-use of propylene oxide, which consumes an estimated 56% of production (1120 million lb), is polyether polyol manufacture for urethane applications. An additional 6% of production was used to produce polyether polyols for surfactant applications. In each of these processes, water or propylene glycol is reacted with propylene oxide to form the polyols.[3]

Specific source locations of the urethane polyol producers are shown in Table 26-3,[4] and the surfactant polyol producers are shown in Table 26-5.[4] An estimated 24% (40 million lb) of propylene oxide was captively consumed to produce propylene glycol. Propylene glycol is made by reacting propylene oxide with water (hydration). Specific source locations of propylene glycol manufacturers are shown in Table 26-4.[6] Minor uses of propylene oxide include di- and tripropylene glycol manufacture (source locations shown in Table 26-6)[5] consume 100 million lb and glycol ethers manufacture (source locations shown in Table 26-7)[1] which consume an estimated

Table 26-1. Propylene Oxide Producers[a]

Company	Location	1978 Capacity (10^6 lb/yr)	Process Used[b]	1978[c] Production (10^6 lb/yr)	Geographical Location Latitude/Longitude
BASF Wyandotte	Wyandotte, Michigan	175	A	109	42 12 55/83 08 35
Dow	Freeport, Texas	1100	A	684	28 59 35/95 23 36
Dow	Plaquemine, LA	340	A	212	30 19 00/91 15 32
Jefferson	Port Neches, Texas	150	A	93	29 57 50/93 56 0
Olin	Brandenburg, Kentucky	130	A	81	38 00 27/86 06 50
Oxirane	Bayport, Texas	920	B	572	29 37 26/95 03 07
Oxirane	Channelview, Texas	400	B	249	29 48 50/95 07 30
	Total	3215		2000	

---

[a] See References 1 and 2.

[b] A = chlorohydrin
B = peroxidation

[c] Based on 62.2% production to capacity ratio.

Table 26-2. Propylene Oxide End-Uses 1978*

Source	Usage (10^6 lb/yr)	% Usage
Urethane polyols	1120	56
Propylene glycol	480	24
Surfactant polyols	120	6
Dipropylene glycol	100	5
Glycol ethers	40	2
Miscellaneous	40	2
Exports	100	5
Total	2000	100

*See ref. 1 and 2.

Table 26-3. Propylene Oxide Users for Urethane Polyols Production[a]

Company	Location	1978 Urethane Polyols Capacity (million lb/yr)	1978[a] Propylene Oxide Used (million lb/yr)	Geographic Coordinates Latitude/Longitude
BASF Wyandotte	Geismar, LA	100	45	30 11 34/91 00 42
	Washington, NJ	40	18	40 45 20/74 58 22
	Wyandotte, MI	225	101	42 12 55/83 08 35
E. R. Carpenter Co.	Bayport, TX	150	68	29 43 20/94 54 00
Dow Chemical Co.	Freeport, TX	400	180	28 59 35/95 23 36
	Midland, MI	20	9	43 34 08/84 16 26
Emery Industries	Mauldin, SC	10	4.5	34 48 16/82 16 09
	Sante Fe Springs, CA	10	4.5	33 55 30/118 05 40
Hodag Chemical Co.	Skokie, IL	10	4.5	42 01 50/87 43 39
Magna Corporation	Houston, TX	12	5	29 40 10/95 23 30
Milliken	Inman, SC	3	1.5	34 56 10/82 06 29
3M	Decatur, AL	15	7	34 38 39/87 02 25
Mobay Chemical Corp.	Baytown, TX	100	45	29 45 30/94 54 25
	New Martinsville, WV	80	36	39 44 50/80 50 55
Nalco Chemical Co.	Sugar Land, TX	40	18	29 37 10/95 38 32
Olin Corporation	Brandenburg, KY	220	100	38 00 26/86 00 50
Owens-Corning	Newark, OH	10	4.5	40 05 30/82 26 00
Pelron Corporation	Lyons, Illinois	22	10	41 44 56/87 49 04

Table 26-3 (concluded)

Company	Location	1978 Urethane Polyols Capacity (million lb/yr)	1978[b] Propylene Oxide Used (million lb/yr)	Geographic Coordinates Latitude/Longitude
Petrolite Corp.	Brea, CA	15	7	33 53 30/117 58 45
	St. Louis, MO	15	7	38 41 50/90 12 00
PPG Industries, Inc.	Circleview, OH	30	14	39 36 05/82 57 34
The Quaker Oats Co.	Memphis, TN	10	4.5	35 10 30/90 56 56
Reichhold	Carteret, NJ	20	9	40 35 56/74 13 13
Jefferson Chem. Co.	Austin, TX	33	15	30 20 00/97 14 15
	Conroe, TX	33	15	30 18 50/95 23 06
	Port Neches, TX	34	15	29 57 50/93 56 0
Union Carbide	Institute, WV	245	110	38 23 02/81 47 24
	Seadrift, TX	245	110	28 30 31/96 46 18
	South Charleston, WV	250	113	38 22 13/81 40 44
Upjohn	LaPorte, TX	14	6	29 42 44/95 04 45
Witco	Clearing, IL	25	11	41 48 02/87 46 39
	Houston, TX	18	8	29 34 45/95 26 00
	Total	2484	1120	

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[a] See refs. 3 and 4.

[b] Based on 56% of propylene oxide produced. Used to make urethane polyols (see refs. 2 and 5)

$$\text{propylene oxide used} = \frac{\text{urethane polyols capacity}}{2484} \times .56\ (2000 \times 10^6 \text{ lb/yr propylene oxide produced}).$$

Table 26-4. Propylene Oxide Users for Propylene Glycol Production[a]

Company	Location	1978 Propylene Glycol Capacity (million lb/yr)	1978[b] Propylene Oxide Used (million lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Freeport, TX	250	140	28 59 35/95 23 36
	Plaquemine, LA	160	91	30 19 00/91 15 32
Jefferson	Port Neches, TX	50	28	29 57 50/93 56 0
Olin	Brandenburg, KY	45	25	38 00 27/86 06 50
Oxirane	Bayport, TX	250	140	29 37 26/95 03 07
Union Carbide	Institute, WV	50	28	38 23 02/81 47 24
	S. Charleston, WV	50	28	38 22 13/81 40 44
	Total	855	480	

[a] See ref. 5.

[b] Based on 24% of propylene oxide produced used to make propylene glycol (see ref. 2).

$$\text{propylene oxide used} = \frac{\text{propylene glycol capacity}}{855} \times 0.24\ (2000 \times 10^6\ \text{lb/yr polylene oxide produced}).$$

Table 26-5. Propylene Oxide Users for Surfactant Polyols Production[a]

Company	Location	Polyether Polyols Capacity (million lb/yr)	Propylene Oxide Used[b] (million lb/yr)	Geographic Coordinates Latitude/Longitude
Emery Industries	Sante Fe Springs, CA	10	2	33 55 30/118 05 40
Olin	Brandenburg, KY	270	51	38 00 26/86 00 50
Petrolite	Brea, CA[c]	15[c]	3	33 53 30/117 58 45
	St. Lcuis, MO	15[c]	3	38 41 50/90 12 00
Sherex	Janesville, WI	5	1	42 40 47/89 00 30
Union Carbide	Institute, WV	100[d]	19	38 23 02/81 47 24
	Seadrift, TX	100[d]	19	28 30 31/96 46 18
	S. Charleston, WV	100[d]	19	38 22 13/81 40 44
Witco	Houston, TX	18	3	29 34 45/95 26 00
	Total	633	120	

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[a] See ref. 4.

[b] Total propylene oxide used distributed over each site based on polyether polyols capacity.

[c] Total capacity of 30 million lb equally distributed between both sites.

[d] Total capacity of 300 million lb equally distributed over all three sites.

Table 26-6. Propylene Oxide Users for Di- and Tripropylene Glycol Production[a]

Company	Location	Dipropylene Glycol/ Tripropylene Glycol Production Capacity (million lb/yr)	Propylene Oxide Used[b] (million lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Freeport, TX	27.5	32.3	28 59 35/95 23 36
	Plaquemine, LA	17.6	20.7	30 19 00/91 15 32
Olin	Brandenburg, KY	5	5.9	30 08 27/86 06 50
Oxirane	Bayport, TX	18	21.1	29 37 26/95 03 07
Jefferson	Port Neches, TX	7	8.2	29 57 50/93 56 00
Union Carbide	Institute, WV	5[c]	5.9	38 23 02/81 47 24
	S. Charleston, WV	5[c]	5.9	38 22 13/81 40 44
	Total	85.1	100.0	

---

[a] See ref. 5.

[b] Total propylene oxide used allocated per site based on the rati of di/tripropylene glycol individual site production capacity to total industry production capacity.

[c] Capacity of 10 million lb/yr equally distributed between the two sites.

Table 26-7. Propylene Oxide Users for Glycol Ethers Production[a]

Company	Location	Propylene Oxide Used[b] (million lb/yr)	Geographic Coordinates Latitude/Longitude
Dow	Freeport, TX	19.5	28 59 35/95 23 36
	Plaquemine, LA	13.0	30 19 00/91 15 32
Olin	Brandenburg, KY	7.5	30 08 27/86 06 50
	Total	40.0	

[a] See ref. 1.

[b] Propylene oxide use allocated over the three sites based on ethylene glycol ethers capacity in the absence of propylene glycol ether figures.

40 million lb. Miscellaneous end-uses of propylene oxide as a chemical intermediate consumed 40 million lb, and exports are estimated to have been 100 million lb.

II. EMISSION ESTIMATES

A. PRODUCTION

Emission estimates from the production of propylene oxide are tabulated in Table 26-8. Total emissions of propylene oxide from production facilities are estimated to have been 1,059,600 lb in 1978. Emission factors used to develop process storage and fugitive emission estimates are shown in Table 26-8.[6,7,8,9] Process emissions originate primarily from the reaction and scrubber vents. Other associated emission components would include propylene, chlorine, and propane from the chlorohydrin process and n-butyl alcohol and octane from the peroxidation process. Storage emissions represent the total losses from working and final product storage tanks as well as loading and handling losses. Fugitive emissions are those caused by leaks from plant equipment. Emission estimates are based on a plant operation schedule of 24 hr per day, 7 days per week, 52 weeks per year.

Vent stack data are reported in Table 26-8. Normally 2 process vents and 2 storage tank vents are involved. Usually propylene oxide production facilities are "open-air" structures without walls and solid floors (steel grating). Only the control room area is enclosed.

B. USES

For the purpose of this report, emissions resulting from the export of propylene oxide are assumed to be negligible.

Table 26-9 shows the emissions of propylene oxide that result from its use in the manufacture of polyether polyols for urethane applications. Total emissions of propylene oxide from this end-use are estimated to have been 245,239 lb in 1978. Emission factors used to develop this estimate are shown in Table 26-9[10] along with vent parameter data. Other associated emissions would include propylene glycols and propylene. Normally one process vent and one storage tank vent are involved.

Table 26-8. EMISSIONS FROM PROPYLENE OXIDE PRODUCERS[a]

Company	Location	Process Vents					Storage Vent Emissions (lbs/yr)	Fugitive Emissions[b] (lb/yr)	Total Emissions	
		Emissions (lb/yr)	Stack Height (m)	Stack Diameter (m)	Stack Velocity (m/sec)	Stack Temp. (°C)			(lb/yr)	(g/sec)
BASF Wyandotte	Wyandotte, MI	81,750	10.4	0.26	2.0	25	3,380	2,290	87,420	1.26
Dow	Freeport, TX	513,000	10.4	0.26	2.0	25	21,200	14,360	548,570	7.90
	Plaquemine, LA	159,000	10.4	0.26	2.0	25	6,570	4,450	170,020	2.45
Jefferson	Port Neches, TX	69,750	7.25	0.19	2.0	46	2,880	1,950	74,590	1.07
Olin	Brandenburg, KY	60,750	10.4	0.26	2.0	25	2,510	1,700	64,960	0.94
Oxirane[c]	Bayport, TX	21,320	9.1	0.05	2.0	21	10,000	17,600	48,920	0.71
	Channelview, TX	52,290	14.6	0.76	2.0	26	7,720	5,230	65,240	0.94
	TOTAL	957,860					54,270	47,590	1,059,720	

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[a] Based on the following emission factors (lb PO lost per lb produced)

Process A -- Chlorohydrination (refs. 6, 9)

Process	0.000750	"B" State air files
Storage	0.000031	"B" State air files
Fugitive	0.000021	"D" Hydroscience estimate
Total	0.000802	

Process B -- Peroxidation (refs. 7, 8)

Process	0.000210	"B" State air files
Storage	0.000031	"B" State air files
Fugitive	0.000021	"D" Hydroscience estimate
Total	0.000262	

[b] Building cross section 200 m^2 distributed over a 350 ft x 1350 ft area.

[c] See ref. 14

Table 26-9. EMISSIONS FROM PROPYLENE OXIDE USERS FOR ERETHANE POLYOLS PRODUCTION*

Company	Location	Process Vents Emissions (lbs/yr)	Process Vents Emissions (g/sec)	Storage Vents Emissions (lb/yr)	Storage Vents Emissions (g/sec)	Fugitive Emissions (lb/yr)	Fugitive Emissions (g/sec)	Total Emissions (lb/yr)	Total Emissions (g/sec)
BASF Wyandotte	Geismar, LA[a]	103,703	1.49	708	0.010	708	0.010	105,119	0.192
	Washington, NJ	2,400	0.03	20		20		2,440	0.03
	Wyandotte,MI	13,200	0.19	100	0.002	80	0.001	13,380	0.193
E. R. Carpenter	Bayport, TX	8,800	0.13	80	0.001	60	0.001	8,940	0.132
Dow	Freeport, TX	23,400	0.34	100	0.003	140	0.002	23,640	0.345
	Midland, MI	1,200	0.02					1,200	0.02
Emery Industry	Maudlin, SC	600	0.01					600	0.01
	Santa Fe Springs, CA	600	0.01					600	0.01
Hodag Chemical	Skokie, IL	600	0.01					600	0.01
Magna	Houston, TX	600	0.01					600	0.01
Milliken	Inman, SC	200						200	
Minnesota Mining & Manufacturing	Decatur, AL	1,000	0.01					1,000	0.01
Mobay	Baytown, TX	5,800	0.08	40	0.001	40	0.001	5,880	0.082
	New Martinsville, WV	4,600	0.07	40	0.001	20		4,660	0.071
Nalco	Sugarland, TX	2,400	0.03	20		20		2,440	0.03
Olin	Brandenburg, KY	12,800	0.19	100	0.002	80	0.001	12,980	0.193
Owens-Corning	Newark, OH	600	0.01					600	0.01
Pelron	Lyons, IL	1,400	0.02	20				1,420	0.02
Petrolite	Brea, CA	1,000	0.01					1,000	0.01
	St. Louis, MO	1,000	0.01					1,000	0.01
PPG Industries	Circleview, OH	1,800	0.03	20		20		1,840	0.03
Quaker Oats	Memphis, TN	600	0.01					600	0.01
Reichhold	Cateret, NJ	1,200	0.02					1,200	0.02
Jefferson	Austin, TX	2,000	0.03	20		20		2,040	0.03
	Conroe, TX	2,000	0.03	20		20		2,040	0.03
	Port Neches, TX	2,000	0.03	20		20		2,040	0.03

Table 26-9. EMISSIONS FROM PROPYLENE OXIDE USERS FOR ERETHANE POLYOLS PRODUCTION* (concluded)

Company	Location	Process Vents Emissions (lbs/yr)	Process Vents Emissions (g/sec)	Storage Vents Emissions lb/yr	Storage Vents Emissions (g/sec)	Fugitive Emissions lb/yr	Fugitive Emissions (g/sec)	Total Emissions (lb/yr)	Total Emissions (g/sec)
Union Carbide	Institute, WV	14,300	0.21	120	0.002	80	0.001	14,500	0.213
	Seadrift, TX	14,300	0.21	120	0.002	80	0.001	14,500	0.213
	S. Charleston, WV	14,600	0.21	120	0.002	80	0.001	14,800	0.213
Upjohn	LaPorte, TX	800	0.01					800	0.01
Witco	Clearing, IL	1,400	0.02	20				1,420	0.02
	Houston, TX	1,000	0.01					1,000	0.01
	Total	241,703		1,768		1,768		245,239	

* Based on the following emission factors (lb PO emmitted per lb PO used): (ref. 10)

Process 0.000130 B - (derived from state air emission files)
Storage 0.000001 B - (derived from state air emission files)
Fugitive 0.000001 B - (derived from state air emission files)

Average process vent stack parameters for all locations are:
13.1 m - stack height
0.03 m - stack diameter
1.1 m/sec - stack velocity
27°C m - stack temperature

Average storage vent parameters:
6 m - stack height
0.03 m - stack diameter
27°C - stack temperature

Building cross section - 100 m^2
Fugitive emissions distributed over a 100 ft x 100 ft area

[a] See ref. 15

[b] The Olin Company's Lake Charles, LA plant no longer emits propylene oxide (ref. 16).

Table 26-10 shows the emissions of propylene oxide that result from its use in the manufacture of propylene glycols. Total emissions of propylene oxide from this end-use are estimated to have been 9,860 lb in 1978. Emission factors used to develop this estimate are shown in Table 26-10[11,12] along with vent parameter data. Other associated emission components would include propylene glycols and propylene. Normally one process vent distillation column and one storage tank vent are involved.

Emissions from storage are reported to be negligible.[11,12] Both di- and tri-propylene glycol are co-products of propylene glycol manufacture.

Table 26-11 shows the propylene oxide emissions resulting from its use in the manufacture of polyether polyols used in surfactant applications. Since most surfactant polyols are produced by the same companies that produce urethane polyols, usually in the same equipment, the emission factors and vent parameter data are assumed to be the same for both end-uses. Total emissions of propylene oxide resulting from this end-use are estimated to have been 15,840 lb in 1978.

Table 26-12 shows the estimated emissions of propylene oxide form the manufacture of dipropylene glycol, tripropylene glycol, and propylene-based glycol ethers. Because these chemicals are all manufactured by the same companies that produce propylene glycol and are integrated units, the emission factors and vent parameter data determined for propylene glycol manufactures are applicable here.[13] Total estimated emissions of propylene oxide from these end-uses are estimated to have been 3450 lb in 1978.

Total nationwide emissions of propylene oxide in 1978 from all sources are estimated to have been 1,337,949 lb. A tabulation of the losses is shown in Table 13.

Table 26-10. Emissions from Propylene Oxide Users for Propylene Glycol Production*

Company	Location	Process Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions (lb/yr)	Total Emissions (g/sec)
Dow	Freeport, TX	3,920	140	4,060	0.058
	Plaquemine, LA	2,550	90	2,640	0.038
Jefferson	Port Neches, TX	785	30	810	0.012
Olin	Brandenburg, KY	700	25	725	0.010
Union Carbide	Institute, WV	785	30	810	0.012
	S. Charleston, WV	785	30	810	0.012
	Total	9,520	340	9,860	

*Based on the following emission factors (lb PO emitted per lb PO used); see refs. 11, 12.

Process	0.000028	B - (derived from state air emission files)
Storage	0.0	B - (derived from state air emission files)
Fugitive	0.000001	B - (derived from state air emission files)
	0.000029	

Average process vent stack parameters for all locations are:

27.4 m - stack height

0.05 m - stack diameter

3.3 m/sec - stack velocity

5°C - stack temperature

Average storage vent stack parameters:

6.0 m - stack height

0.03 m - stack diameter

27°C - stack temperature

Building cross-section, 200 m^2

Fugitive emissions distributed over a 350 ft X 1350 ft area.

Table 26-11. Emissions from Surfactant Polyol Producers

Company	Location	Process Emissions (lb/yr)	Storage Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions[a] (lb/yr)	Total Emissions[a] (g/sec)[b]
Emery	Santa Fe Springs, CA	260	nil	nil	265	0.004
Olin	Brandenburg, KY	6630	50	50	6730	0.097
Petrolite	Brea, CA	390	nil	nil	395	0.006
	St. Louis, MO	390	nil	nil	395	0.006
Sherex	Janesville, WI	130	nil	nil	130	0.002
Union Carbide	Institute, WV	2470	20	20	2510	0.036
	Seadrift, TX	2470	20	20	2510	0.036
	S. Charleston, WV	2470	20	20	2510	0.036
Witco	Houston, TX	390	nil	nil	395	0.006
	Total	15,600	120	120	15,840	

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[a] Based on urethane polyols emission factor since both are produced in the same equipment.

[b] Based on 8760 hr/yr operation.

Table 26-12. Emissions from Dipropylene Glycol, Tripropylene Glycol, and Glycol Ether Producers

Company	Location	Process Emissions (lb/yr)	Fugitive Emissions (lb/yr)	Total Emissions^a (lb/yr)	(g/sec)
Dow	Freeport, TX	1450	50	1500	0.022
	Plaquemine, LA	945	35	980	0.014
Olin	Brandenburg, KY	375	15	390	0.006
Jefferson	Port Neches, TX	230	10	240	0.003
Union Carbide	Institute, WV	165	5	170	0.002
	S. Charleston, WV	165	5	170	0.002
	Total	3,330	120	3,450	

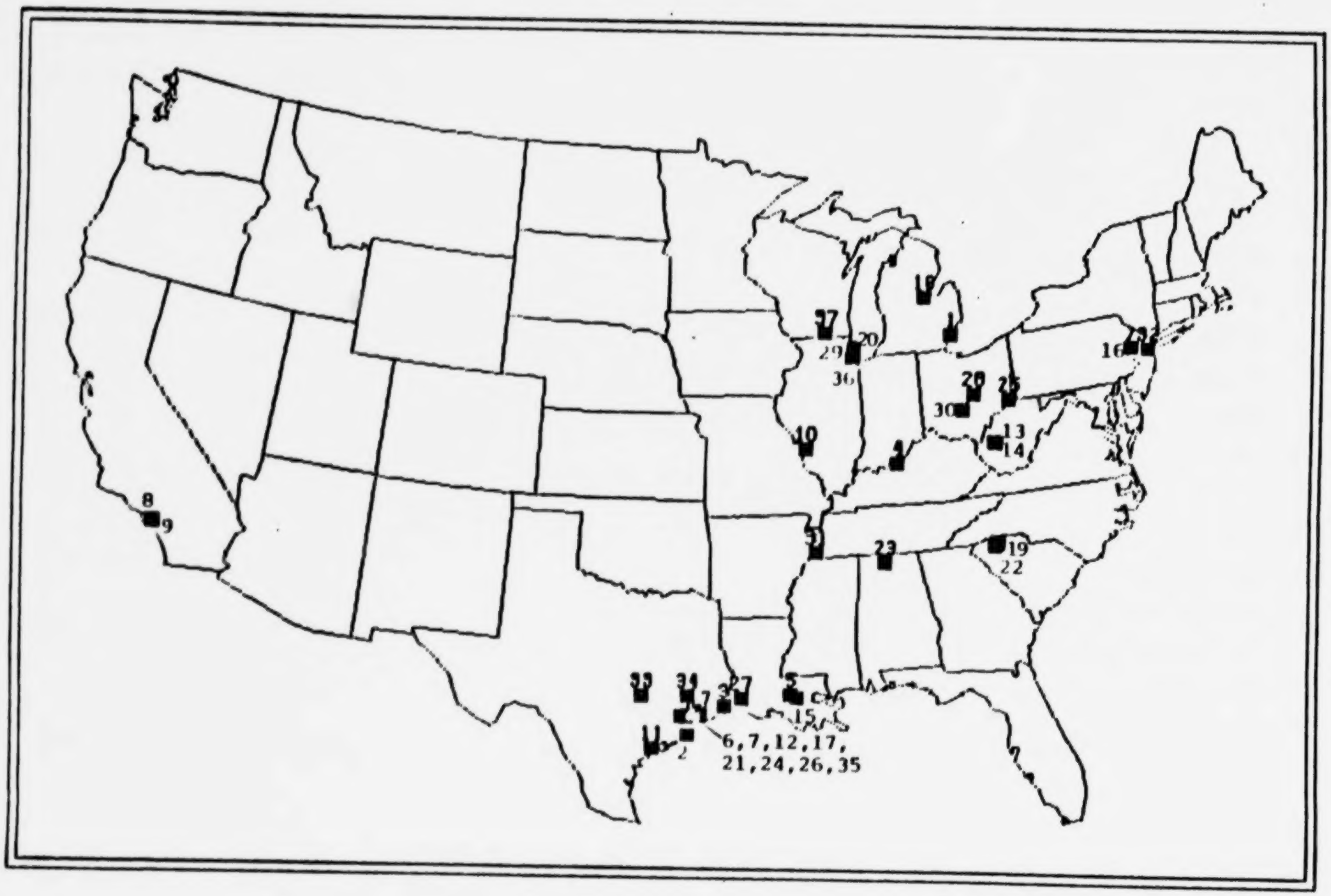
[a] Based on propylene glycol emission factor; see ref. 13.

[b] Based on 8760 hr/yr operation.

Table 26-13. 1978 Propylene Oxide Nationwide Emissions

Source	Estimated 1978 Emissions (lb/yr)
Production	1,059,720
Urethane polyols	245,239
Propylene glycol	9,860
Surfactant polyols	15,840
Di/tri-propylene glycols	2,290
Glycol ethers	1,160
Miscellaneous	3,840*
Exports	0
Total	1,337,949

*Derived based on weighted average of other users except exports.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21,24,26,35

FIGURE 26-1. SPECIFIC POINT SOURCES OF PROPYLENE OXIDE EMISSIONS

Table 26-14. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PROPYLENE OXIDE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	BASF WYANDOTTE	WYANDOTTE, MI	42 12 55	083 08 35	14822	1	1	1.177194	.049060	.029775
							2	.190068	.001427	.001142
2	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	2	1	7.387240	.305302	.206780
							2	.336948	.001427	.002029
							4	.077340	0.	.002727
3	JEFFERSON	PORT NECHES, TX	29 57 45	093 56 00	12917	2	1	1.004440	.041476	.028095
							2	.028792	.000285	.000285
							4	.014618	0.	.000571
4	OLIN	BRANDENBURG, KY	38 00 27	086 06 50	13807	3	1	.874810	.036150	.024480
							2	.184329	.001427	.001142
							3	.095478	.000729	.000729
							4	.015474	0.	.000571
5	DOW	PLAQUEMINE, LA	30 19 00	091 15 00	13970	4	1	2.289574	.094625	.064085
							4	.050387	0.	.001870
6	OXIRANE	BAYPORT, TX	29 37 26	095 03 07	12906	4	1	.306665	.143836	.253139
7	OXIRANE	CHANNELVIEW, TX	29 48 50	095 07 30	12906	5	1	.752980	.111174	.075311
8	EMERY	SANTA FE SPGS, CA	33 55 30	118 05 40	23174	6	2	.008625	0.	0.
							3	.095478	0.	0.
9	PETROLITE	BREA, CA	33 53 30	117 58 45	23174	6	2	.014396	0.	0.
							3	.005613	0.	0.
10	PETROLITE	ST. LOUIS, MO	38 41 50	090 12 00	13994	6	2	.014396	0.	0.
							3	.005613	0.	0.
11	UNION CARBIDE	SEADRIFT, TX	28 30 31	096 46 18	12923	6	2	.205923	.001712	.001142
							3	.035578	.000285	.000285
12	WITCO	HOUSTON, TX	29 34 45	095 26 00	12906	6	2	.014396	0.	0.
							3	.005613	0.	0.

Table 26-14. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF PROPYLENE OXIDE (Continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
13	UNION CARBIDE	INSTITUTE, WV	38 23 02	081 47 24	13866	7	2	.205923	.001712	.001142
							3	.035578	.000285	.000285
							4	.013667	0.	.000507
14	UNION CARBIDE	SO CHARLESTON, WV	38 19 35	081 40 29	13866	7	2	.210236	.001712	.001142
							3	.035578	.000285	.000285
							4	.013667	0.	.000507
15	BASF WYANDOTTE	GEISMAR, LA	30 11 34	091 00 42	13970	8	2	1.491597	.010179	.010179
16	BASF WYANDOTTE	WASHINGTON,NJ	40 45 20	074 58 22	04789	8	2	.083524	.000571	.000571
17	ER CARPENTER	BAYPORT, TX	29 43 20	094 54 00	12906	8	2	.126712	.001142	.000856
18	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	8	2	.017282	0.	0.
19	EMERY	MAUDLIN, SC	34 48 16	082 16 09	93804	8	2	.008625	0.	0.
20	HODAG	SKOKIE, IL	42 01 50	087 43 39	14855	8	2	.008625	0.	0.
21	MAGNA	HOUSTON, TX	29 40 10	095 23 30	12906	8	2	.008625	0.	0.
22	MILLIKEN	INMAN, SC	34 56 10	082 06 29	93804	8	2	.002886	0.	0.
23	3M	DECATUR, AL	34 38 39	087 02 25	13882	8	2	.014396	0.	0.
24	MOBAY	BAYTOWN, TX	29 45 30	094 54 25	12906	8	2	.083524	.000571	.000571
25	MOBAY	NEW MARTINSVILLE,WV	39 44 50	080 50 50	13736	8	2	.066242	.000571	.000285
26	NALCO	SUGARLAND, TX	29 37 10	095 38 32	12906	8	2	.034564	.000285	.000285
27	OWENS CORNING	NEWARK, OH	40 05 30	082 26 00	93824	8	2	.008625	0.	0.
28	PELRON	LYONS, IL	41 44 56	087 49 04	94846	8	2	.020167	.000285	0.
29	PPG	CIRCLEVIEW, OH	39 36 05	082 57 34	93824	8	2	.025907	.000285	.000285
30	QUAKER OATS	MEMPHIS, TN	35 10 30	089 56 56	13963	8	2	.008625	0.	0.

Table 26-14 (Concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
32	REICHOLD	CATTERET, NJ	49 35 56	074 13 13	94741	8	2	.017285	0.	0.
33	JEFFERSON	AUSTIN, TX	30 20 00	097 14 15	13958	8	2	.028792	.000285	.000285
34	JEFFERSON	CONROE, TX	30 18 50	095 23 06	12960	8	2	.028792	.000285	.000285
35	UPJOHN	LAPORTE, TX	29 42 26	095 04 29	12906	8	2	.011511	0.	0.
36	WITCO	CLEARING, IL	41 48 02	087 46 39	94846	8	2	.020167	.000285	0.
37	SHEREX	JAMESVILLE, WI	42 40 47	089 00 30	14837	9	3	.001871	0.	0.

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*Plant types:

Type 1: Plant produces propylene oxide and urethane polyols
Type 2: Plant produces propylene oxide, urethane polyols, and glycols
Type 3: Plant produces propylene oxide surfactant polyols and glycols
Type 4: Plant produces propylene oxide and glycols
Type 5: Plant produces propylene oxide
Type 6: Plant produces urethane polyols and surfactant polyols
Type 7: Plant produces urethane polyols, surfactant polyols and glycols
Type 8: Plant produces urethane polyols
Type 9: Plant produces surfactant polyols

+ Source types:

Type 1: Propylene oxide production
Type 2: Urethane polyols production
Type 3: Surfactant polyols productin
Type 4: Propylene glycol production/Di/tripropylene glycol/glycol ether production

Table 26-15. EXPOSURE AND DOSAGE OF PROPYLENE OXIDE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
250	2	499
100	14	2,310
50	58	5,040
25	459	18,300
10	2,515	48,600
5	5,658	71,400
2.5	14,670	103,000
1	64,361	177,000
0.5	167,900	247,000
0.25	441,716	342,000
0.1	936,879	420,000
0.05	1,636,769	470,000
0.025	2,778,117	510,000
0.01	4,497,702	539,000
0.005	5,480,715	546,000
0.0025	7,121,386	552,100
0.001	11,549,809	559,000
4.36 x 10^{-5}*	12,323,453	560,000

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*The lowest annual average concentration occuring within 20 km of the specific point source.

TABLE 26-16. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF PROPYLENE OXIDE

Parameter	Value
Daytime decay rate (K_d)	1.4×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	0.055 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 26-17. PROPYLENE OXIDE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
.000250	446952	133.7	0.	100.0	0.	100.0	0.	0.
.000100	9149730	1118.6	0.	100.0	0.	100.0	0.	0.
.000050	17551646	1596.0	0.	100.0	0.	100.0	0.	0.
.000025	40970419	2412.9	0.	100.0	0.	99.3	.1	.7
.000010	120132422	3680.4	0.	100.0	0.	95.7	2.0	2.3
0.	158679135	3930.4	0.	100.0	0.	92.8	2.6	4.6

TABLE 26-18. EXPOSURE AND DOSAGE SUMMARY OF PROPYLENE OXIDE

Concentration Level (ug/m^3)	Population Exposed (Persons)				Dosage [(ug/m^3) . persons]			
	Specific Point Source	General Point Source	Area Source	U. S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
250	2	0	0	2	499	0	0	499
100	14	0	0	14	2,310	0	0	2,310
50	58	0	0	58	5,040	0	0	5,040
25	459	0	0	459	18,300	0	0	18,300
10	2,515	0	0	2,515	48,600	0	0	48,600
5	5,658	0	0	5,658	71,400	0	0	71,400
2.5	14,670	0	0	14,670	103,000	0	0	103,000
1	64,361	0	0	64,361	177,000	0	0	177,000
0.5	167,900	0	0	167,900	247,000	0	0	247,000
0.25	441,716	0	0	441,716	342,000	0	0	342,000
0.1	936,879	0	0	936,879	420,000	0	0	420,000
0.05	1,636,769	0	0	1,636,769	470,000	0	0	470,000
0.025	2,778,117	0	0	2,778,117	510,000	0	0	510,000
0.01	4,497,702	0	0	4,497,702	539,000	0	0	539,000
0.005	5,480,715	0	0	5,480,715	546,000	0	0	546,000
0.0025	7,121,386	0	0	7,121,380	552,000	0	0	552,000
0.001	11,549,809	0	0	11,549,809	559,000	0	0	559,000
0.00025	--	0	446,952	--	--	0	134	--
0.0001	--	0	9,149,730	--	--	0	1,118	--
0	12,323,453	0	158,679,135	171,002,588	560,000	0	3,930	563,930

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-27 ----- Toluene

TOLUENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-88-3

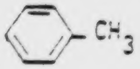
Synonyms: Methyl Benzene; Phenyl Methane; Toluol; Methacide

Chemical Formula

Molecular Weight: 9 15

Molecular Formula: H_8

Molecular Structure



Chemical and Physical P rties

Physical State at Liquid-flammable, refractive, clear, noncorrosive, sweet odor

Boiling Point: 1 °C at 760 mm

Melting Point: -

Density: 0.8669)°C/4°C

Vapor Pressure: mm at 25°C

Vapor Density: 3

Solubility: sli soluble (4.7 g/l of H_2O)

Log Partition Co ient (Octanol/H_2O): 2.80

Atmospheric Reactivit

Transformation P ts: reacts with oxidizing materials. Forms organic aerosols (5-10%), Formal , and Cresols (10%), Benzaldehyde, benzoic acid

Reactivity Towa : 2 x Butane

Reactivity Towa No Reaction

Reactivity Towa tolysis: none - NAPP

Major Atmospher cursors: N/A

Formation React

I. SOURCES

A. PRODUCTION

Toluene is produced as an aromatic mixture (BTX) with benzene and mixed xylenes primarily from catalytic reformate from refineries. It is also produced as BTX from petroleum-derived pyrolysis gasoline as a by-product of olefin manufacture during the cracking of hydrocarbons. Small amounts of toluene as BTX are also obtained from coal-derived coke oven light oil and as a by-product from the manufacture of styrene.[1,2]

Approximately 9,195 million lb of toluene was isolated from a total of 66,930 million lb of toluene produced as BTX. The isolated toluene is used primarily for chemical manufacturing and as a solvent.[1,2]

The largest source of toluene is from catalytic reformate. Total estimated toluene produced from this source is estimated to have been 64,875 million lb with 7,943 million lb isolated for chemical use. Catalytic reforming involves the dehydrogenation of selected petroleum fractions rich in naphthalenes in the presence of hydrogen to yield a mixture of aromatics consisting of toluene, benzene, and mixed xylenes. Toluene is isolated by distillation followed by washing with sulfuric acid and redistillation.[1,2]

The second largest source of toluene is from pyrolysis gasoline. An estimated 1274 million lb of toluene was produced from this source with an estimated 586 million lb isolated for chemical use.

An estimated 320 million lb of toluene was produced as a by-product of styrene manufacture with 220 million lb isolated for chemical use.[1,2]

Approximately 175 million lb of toluene was produced from coal-derived BTX with an estimated 145 million lb isolated for chemical use.[1,2]

There are currently 200 locations that produce toluene as BTX from catalytic reformate. They are shown in Table 27-1 by geographic region.[3] Of this total, only 32 plants isolate toluene from catalytic reformate. Three of these sites are located outside the continental United States and were not considered in

Table 27-1. Nonisolated Toluene Production from Catalytic Reformate[a]

Region	Number of Sites	Reformate Capacity (M bbl/day)	Nonisolated Toluene Produced (M̄ lb/yr)[b]	Average Nonisolated Toluene Produced Per Site (M̄ lb/yr)
New England	0	0	0	0
Middle Atlantic	17	369,952	5,564	327
East North Central	28	624,178	9,388	335
West North Central	16	165,250	2,485	155
South Atlantic	5	57,660	868	174
East South Central	8	144,700	2,176	272
West South Central	71	1,649,303	24,805	349
Mountain	23	123,094	1,851	80
Pacific	33	647,461	9,738	295
Total	201	3,781,598	56,875	283

[a] See ref. 3.

[b] Total production distributed based on total capacity.

the project scope. The locations of the plants, the isolated toluene capacity, and the isolated toluene production are shown in Table 27-2.[1,2]

There are currently eight producers at eight locations that produce toluene as BTX from pyrolysis gasoline manufacture. One of the sites is in Puerto Rico and was considered outside the project scope. The locations of the plants, the ethylene capacity, the estimated toluene production as BTX and as isolated toluene, and the total toluene produced are shown in Table 27-3.[1,2]

The six locations that produce coal-derived toluene and the seven sites that produce toluene as a styrene by-product are also listed in Table 27-3.

A production summary of the sources of isolated toluene and toluene as BTX are shown in Table 27-4[1,2] along with toluene's 1978 end-use distribution.

B. USES

As noted above, the end-use distribution of toluene is shown in Table 27-4. All toluene produced as BTX and not isolated (57,693) million lb) is blended into gasoline. The remaining isolated toluene (8,894) million lb) has a large variety of end-uses.

The single largest end-use of toluene is in the manufacture of benzene through dealkylation which consumes an estimated 3693 million lb and represents 40.2% of isolated toluene production. Specific source locations of benzene producers are shown in Table 27-5. The second largest use of isolated toluene is backblending into gasoline. This end-use consumed an estimated 3230 million lb of isolated toluene, representing 35.1% of 1978 production.

Toluene is the most important of the three major aromatics in solvent applications, and this end-use accounts for an estimated 9.5% of isolated toluene production. The major use of toluene as solvent is in paints and coatings formulations which consumed an estimated 579 million lb. A significant amount, 291 million lb, was used in adhesives, inks, pharmaceuticals, and other formulated products requiring a solvent carrier.

Table 27-2. Isolated Toluene Production from Catalytic Reformate[a]

Company	Location	Toluene Capacity (metric ton/yr)	Isolated Toluene Produced ($\bar{M}$ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Amerada Hess	St. Croix, VI	460	798	Not in project scope
American Petrofina	Big Spring, TX	164	285	32 17 10/101 25 17
	Beaumont, TX	125	217	29 57 30/93 53 20
Ashland Oil	Catlettsburg, KY	99	171	38 22 39/82 35 58
	N. Tonawanda, NY	39	68	42 59 45/78 55 27
ARCO	Houston, TX	118	217	29 42 17/95 16 01
	Wilmington, CA	46	85	33 48 15/118 17 22
Charter Oil	Houston, TX	53	68	29 42 50/95 15 12
Coastal States	Corpus Christi, TX	56	97	27 48 43/97 26 28
Commonwealth	Penuelas, PR	395	684	Not in project scope
Crown	Pasadena, TX	46	80	29 44 40/95 10 30
Exxon	Baytown, TX	411	713	29 44 50/95 01 04
Getty	El Dorado, KA	13	34	37 47 10/96 52 00
Gulf	Alliance, LA	207	336	29 50 00/90 00 10
	Philadelphia, PA	92	160	39 54 00/75 12 30
	Port Arthur, TX	49	86	29 51 30/93 58 30
Kerr McGee	Corpus Christi, TX	148	257	27 48 16/97 25 24
Marathon	Texas City, TX	72	125	29 22 22/94 54 58
Mobile	Beaumont, TX	280	485	30 04 00/94 03 30

Table 27-2 (concluded)

Company	Location	Toluene Capacity (metric ton/yr)	Isolated Toluene Produced (M̄ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Phillips	Sweeny, TX	33	57	29 04 48/95 44 46
	Guayama, PR	335	582	Not in project scope
Quintana-Howell	Corpus Christi, TX	56	97	27 48 35/97 27 30
Shell	Deer Park, TX	197	342	29 42 55/95 07 33
Sun	Corpus Christi, TX	138	239	27 49 53/97 31 30
	Marcus Hook, PA	151	262	39 48 45/75 24 51
	Toledo, OH	247	428	41 36 52/83 31 40
	Tulsa, OK	66	114	36 08 18/96 01 18
Tenneco	Chalmette, LA	99	200	30 03 30/89 58 30
Texaco	Port Arthur, TX	92	160	29 52 00/93 54 43
	Westville, NJ	132	228	39 52 05/75 08 42
Union Oil	Chicago, IL	56	97	41 38 33/88 03 02
Union Pacific	Corpus Christi, TX	99	171	27 48 10/97 35 29
Total		4,574	7,943	

[a] See refs. 1 and 2.

[b] Total isolated toluene production distributed per toluene extraction capacity.

Table 27-3. Other Toluene Producers[a]

Company	Location	1978 Production Capacity ($\bar{M}$ lb)	1978 Toluene Produced as BTX ($\bar{M}$ lb)[b]	1978 Toluene Isolated ($\bar{M}$ lb)[b]	1978 Total Toluene Produced ($\bar{M}$ lb)	Geographic Coordinates Latitude/Longitude
		Pyrolysis Gasoline				
ARCO	Chanelview, TX	1,179	145	195	340	29 50 04/95 06 43
Commonwealth	Penuelas, PR	454	56	92	148	NIPS[c]
Dow	Freeport, TX	1,134	140	24	164	28 59 12/95 01 00
Exxon	Baton Rouge, LA	816	101	-	101	30 09 10/90 54 20
Gulf	Cedar Bayou, TX	544	67	122	189	29 49 29/94 55 10
Mobile	Beaumont, TX	408	50	31	81	30 04 00/94 03 30
Shell	Deer Park, TX	624	77	-	77	29 92 55/95 07 33
Union Carbide	Taft, LA	417	52	122	174	29 58 00/90 27 00
Total		5,576	688	586	1,274	
		Coal Derived				
Ashland	Catlettsburg, KY	33	12	58	70	38 22 39/82 35 55
	N. Tonawanda, NY	10	4	17	21	42 59 45/78 55 27
Bethlehem Steel	Sparrows Point, MD	3	1	6	7	42 49 31/78 51 17
Jones & Laughlin	Aliquippa, PA	7	3	12	15	40 35 54/80 14 24
U.S. Steel	Clairton, PA	26	9	46	55	40 18 15/79 52 43
	Geneva, UT	3	1	6	7	40 19 01/111 44 29
Total		82[d]	30	145	175	

Table 27-3 (concluded)

Company	Location	1978 Production Capacity (M lb)	1978 Toluene Produced as BTX (M lb)[b]	1978 Toluene Isolated (M lb)[b]	1978 Total Toluene Produced (M lb)	Geographic Coordinates Latitude/Longitude
		Styrene By-Product				
American Hoechst	Baton Rouge, LA	990	15	32	47	30 33 02/91 15 50
Cos-Mar	Carville, LA	1,300	19	42	61	30 13 30/91 04 00
Dow	Freeport, TX	1,500	22	49	71	28 59 12/95 01 00
	Midland, MI	325	5	11	16	43 35 28/84 13 08
Gulf	Donaldsonville, LA	600	9	19	28	30 03 30/90 56 10
Monsanto	Texas City, TX	1,500	22	[illegible]	71	29 22 45/94 33 30
Amoco	Texas City, TX	540	8	18	26	29 21 40/94 55 50
Total		6,755	100	220	320	

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[a] See refs. 1 and 2.

[b] Distributed based on production capacity.

[c] Not in project scope.

[d] Metric tons toluene extraction capacity.

Table 27-4. Toluene Production and Consumption*

Source	Isolated Toluene (M lb)	Toluene in BTX (M lb)	Total Toluene Produced (M lb)
	Production		
Catalytic reformate	7,943	56,875	64,818
Pyrolysis gasoline	586	688	1,274
Coal derived	145	30	175
Styrene by-product	220	100	320
Total	8,894	57,693	66,587

End-Use Consumption

End Use	Isolated Toluene Used (%)	Toluene Used (M lb/yr)
Gasoline as BTX		57,693
Gasoline isolated (back blended)	35.1	3,230
Benzene dealkylation	40.2	3,693
Paints and coating solvent	6.3	579
Adhesives, inks, pharmaceuticals solvent	3.2	291
Toluene diisocyanate	4.8	440
Xylenes (disproportionation)	2.3	216
Benzoic acid	1.6	144
Benzyl chloride	0.8	79
Vinyl toluene	0.6	55
Benzaldehyde	0.2	18
p-Cresol	0.1	14
Miscellaneous others	0.6	53
Net export	4.2	383
Total	100.0	66,888

*See refs. 1 and 2.

Table 27-5. Benzene Producers[a]

Company	Location	Benzene Production Capacity (M̄ gal/yr)	Toluene Used (M̄ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
American Petrofina	Port Arthur, TX	23	131	29 57 30/93 53 20
	Big Spring, TX	40	228	32 17 10/101 25 17
Ashland Oil	Catlettsburg, KY	35	200	38 22 39/82 35 58
Coastal States	Corpus Christi, TX	60	343	27 48 43/97 26 28
Commonwealth	Penuelas, PR	115	657	NIPS[c]
Crown	Pasadena, TX	23	131	29 44 40/95 10 30
Dow	Freeport, TX	25	143	28 59 15/95 24 25
Gulf	Alliance, LA	47	268	29 50 00/90 00 19
	Philadelphia, PA	20	114	39 54 00/75 12 30
Monsanto	Alvin, TX	40	228	29 14 55/95 12 45
Phillips	Guayama, PR	40	228	NIPS[c]
Quintana-Howell	Corpus Christi, TX	74	422	27 48 35/97 27 30
Shell	Odessa, TX	7	40	31 49 14/102 19 53
Sun	Corpus Christi, TX	20	114	27 50 00/97 31 25
	Toledo, OH	63	360	41 36 52/83 31 40
	Tulsa, OK	15	86	36 08 18/96 01 18
Total		647	3693	

[a] See refs. 1 and 2.

[b] Total usage distributed per benzene capacity.

[c] Not in project scope.

Other major uses of isolated toluene include toluene diisocyanate production (440 million lb), xylenes via disproportionation (216 million lb), benzoic acid manufacture (139 million lb), benzyl chloride production (43 million lb), vinyl toluene manufacture (55 million lb), benzaldehyde manufacture (18 million lb), and p-cresol production (14 million lb). Net exports consumed 383 million lb of production, and 53 million lb of toluene was consumed in other miscellaneous, unidentifiable uses.

Locations producing toluene diisocyanate are listed in Table 27-6.[1,2] All other chemical intermediate users of toluene are listed in Table 27-7.[1,2,4]

C. INCIDENTAL USES

For the purpose of this report, the use of toluene in gasoline and the emissions resulting from gasoline evaporation and exhaust are considered incidental. The only other source of toluene assessed for emissions was coke ovens.

Gasoline consumption in 1978 is estimated to have been 104,568 million gal.[2]

Coal tars from coke oven plants contain toluene. The total estimated coke production from 61 plants in 1978 was 107 billion lb.[5]

II. EMISSIONS

A. PRODUCTION

Emission factors used to develop production and end-use emission estimates for toluene are shown in Tables 27-8,27-6---27-13.

Emissions from the production of nonisolated toluene from catalytic reformate are tabulated by geographic region in Table 27-9. Emissions from the production of isolated toluene from catalytic reformate are tabulated in Table 27-10. Emissions from the production of toluene from pyrolysis gasoline and coal-derived and styrene by-product are tabulated in Table 27-11.

Emission factors used to develop process, storage, and fugitive emission estimates are shown in Table 27-8. Process emissions are those that originate

Table 27-6. Toluene Diisocyanate Producers[a]

Company	Location	1978 TDI Capacity (10^6 lb/yr)	1978 Toluene Use[b] (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
Allied Chemical	Moundsville, WV	80	44	39 54 39/80 44 49
BASF Wyandotte	Geismar, LA	100	55	30 11 34/90 00 42
Dow Chemical	Freeport, TX	100	55	28 59 12/95 24 05
Du Pont	Deepwater, NJ	70	38	39 41 25/75 30 35
Mobay Chem. Corp	Baytown, TX	130	71	29 45 30/94 54 25
	New Martinsville, WV	100	55	39 44 50/80 50 50
Olin Corp.	Ashtabula, OH	30	16	41 53 07/80 45 50
	Lake Chrales, LA	100	55	30 13 55/93 15 57
Rubicon Chems. Inc.	Geismar, LA	40	22	30 12 00/91 11 30
Union Carbide	S. Charleston, WV	55	29	38 19 35/81 40 29
Total		805	440	

[a] See refs. 1 and 2.

[b] Total usage distributed per TDI capacity.

Table 27-7. Other Toluene Chemical Intermediate Users[a]

Company	Location	Production Capacity (10^6 lb/yr)	Toluene[b] Used (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
		Benzyl Chloride Producers		
Monsanto	Bridgeport, NJ	80	36	39 47 33/75 23 45
Stauffer	Edison, NJ	12	6	40 29 23/74 23 03
UOP, Inc.	E. Rutherford, NJ	3	1	40 49 46/74 05 30
Total		95	43	
		Benzoic Acid Producers		
Kalama	Kalama, WA	140	72	46 00 54/122 51 05
Velsicol	Beaumont, TX	50	26	29 58 16/94 03 17
	Chattanooga, TN	60	31	30 36 31/85 16 36
Pfizer	Terre Haute, IN	6	3	39 26 01/87 24 22
Tenneco	Garfield, NJ	15	7	40 52 28/74 06 49
Total		271	139	
		Xylene Disproportionation Producers		
ARCO	Houston, TX	196	106	29 42 17/95 16 01
Sun	Marcus Hook, PA	202	110	39 48 45/75 24 51
Total		398	216	
		Vinyl Toluene Producer		
Dow	Midland, MI	60	55	43 35 28/84 13 08
		p-Cresol Producer		
Sherwin Williams	Chicago, IL	NA[c]	14	41 43 04/87 36 30

Table 27-7 (concluded)

Company	Location	1978 Production Capacity (10^6 lb/yr)	1978[b] Toluene Used (10^6 lb/yr)	Geographic Coordinates Latitude/Longitude
		Benzaldehyde Producers		
Kalama	Kalama, WA	NA	3.6	46 00 54/122 51 05
	Eddystone, PA	NA	3.6	39 50 58/75 20 00
Stauffer	Edison, NJ	NA	3.6	40 29 23/74 23 07
Tenneco	Garfield, NJ	NA	3.6	40 52 28/74 06 49
UOP	E. Rutherford, NJ	NA	3.6	40 49 46/74 05 30
Total		NA	18[d]	

[a] See refs. 1, 2, and 4.

[b] Total usage distributed per production capacity.

[c] Not available

[d] Total usage distributed evenly over all sites.

Table 27-8. Toluene Emission Factors

Source	Emission Factor lb Lost/lb Produced (Used)				
	Process	Storage	Fugitive	Total	Derivation[a]
Toluene production - catalytic reformate	0.00002	0.00006	0.00002	0.00010	B[b]
Toluene production - pyrolysis gasoline	0.00015	0.00060	0.00015	0.00090	A[c]
Toluene production - coal derived	0.00050	0.00060	0.00015	0.00125	D
Toluene production - styrene by-product	0.00001	0.00060	0.00015	0.00076	A[d]
Benzoic acid production	0.00100	0.00040	0.00010	0.00150	C[e]
Benzyl chloride production	0.00055	0.00030	0.00015	0.00100	C[e]
Vinyl toluene production	0.00055	0.00030	0.00015	0.00100	D
Benzene production	0.00005	0.00010	0.00005	0.00020	B[f]
Xylene disproportionation	0.00005	0.00010	0.00005	0.00020	D
Toluene diisocyanate production	0.00077	0.00032	0.00019	0.00128	C[e]
p-Cresol production	0.00120	0.00050	0.00030	0.00200	D
Benzaldehyde production	0.00090	0.00040	0.00020	0.00150	D

[a] A - Site visit data
B - State files
C - Published data
D - Hydroscience estimate

[b] See refs. 6—10.

[c] See ref. 11.

[d] See ref. 12.

[e] See ref. 13.

[f] See refs. 6, 7, and 9.

Table 27-9. Toluene Emissions from Nonisolated Toluene Produced as BTX from Catalytic Reformate

Region	Number of Sites[a]	Toluene Emissions (lb/yr)[b]	Average Toluene Emissions per Site	
			(lb/yr)	(g/sec)[c]
New England	0	0	0	0
Middle Atlantic	17	556,400	32,730	0.47
East North Central	28	938,800	33,530	0.48
West North Central	16	248,500	15,530	0.22
South Atlantic	5	86,800	17,360	0.25
East South Central	8	217,600	27,200	0.39
West South Central	71	2,480,500	34,940	0.50
Mountain	23	185,100	8,050	0.12
Pacific	33	973,800	29,510	0.42
Total	201	5,687,500		

[a] See ref. 3.

[b] Based on the following emission factor:

lb toluene lost per lb produced

0.00002 Process

0.00006 Storage

0.00002 Fugitive

0.00010 Total

[c] Based on 8760 hr/yr operation.

Table 27-10. Toluene Emissions from Catalytic Reformate Isolated Toluene Production

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
Amerada Hess	St. Croix, VI	15,960	47,880	15,960	79,800	1.15
American Petrofina	Big Spring, TX	5,700	17,100	5,700	28,500	0.41
	Beaumont, TX	4,340	13,020	4,340	21,700	0.31
Ashland Oil	Catlettsburg, KY	3,420	10,260	3,420	17,100	0.25
	N. Tonawanda, NY	1,360	4,080	1,360	6,800	0.10
ARCO	Houston, TX	4,340	13,020	4,340	21,700	0.31
	Wilmington, CA	1,700	5,100	1,700	8,500	0.12
Charter Oil	Houston, TX	1,360	4,080	1,360	6,800	0.10
Coastal States	Corpus Christi, TX	1,940	5,820	1,940	9,700	0.14
Commonwealth	Penuelas, PR	13,680	41,040	13,680	68,400	0.98
Crown	Pasadena, TX	1,600	4,800	1,600	8,000	0.12
Exxon	Baytown, TX	14,260	42,780	14,260	71,300	1.03
Getty	El Dorado, KS	680	2,040	680	3,400	0.05
Gulf	Alliance, LA	6,720	20,160	6,720	33,600	0.48
	Philadelphia, PA	3,200	9,600	3,200	16,000	0.23
	Port Arthur, TX	1,720	5,160	1,720	8,600	0.12
Kerr McGee	Corpus Christi, TX	5,140	15,420	5,140	25,700	0.37
Marathon	Texas City, TX	2,500	7,500	2,500	12,500	0.18
Mobil	Beaumont, TX	9,700	29,100	9,700	48,500	0.70
Phillips	Sweeny, TX	1,140	3,420	1,140	5,700	0.08
	Guayama, PR	11,640	34,920	11,640	58,200	0.84
Quintana-Howell	Corpus Christi, TX	1,940	5,820	1,940	9,700	0.14

Table 27-10 (concluded)

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
Shell	Deer Park, TX	6,840	20,520	6,840	34,200	0.49
Sun	Corpus Christi, TX	4,780	14,340	4,780	23,900	0.34
	Marcus Hook, PA	5,240	15,720	5,240	26,200	0.38
	Toledo, OH	8,560	25,680	8,560	42,800	0.62
	Tulsa, OK	2,280	6,840	2,280	11,400	0.16
Tenneco	Chalmette, LA	4,000	12,000	4,000	20,000	0.29
Texaco	Port Arthur, TX	3,200	9,600	3,200	16,000	0.23
	Westville, NJ	4,560	13,680	4,560	22,800	0.33
Union Oil	Chicago, IL	1,940	5,820	1,940	9,700	0.14
Union Pacific	Corpus Christi, TX	3,420	10,260	3,420	17,100	0.25
Total		158,860	476,580	158,860	794,300	

*Based on 8760 hr/yr operation.

Table 27-11. Toluene Emissions from Pyrolysis Gasoline, Coal-Derived and Styrene By-Product Production

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		Pyrolysis Gasoline				
ARCO[a]	Channelview, TX	0	10,940	860	11,800	0.17
Commonwealth	Penuelas, PR	22,200	88,800	22,200	133,200	1.92
Dow	Freeport, TX	24,600	98,400	24,600	147,600	2.12
Exxon	Baton Rouge, LA	15,150	60,600	15,150	90,900	1.31
Gulf	Cedar Bayou, TX	28,350	113,400	28,350	170,100	2.45
Mobil	Beaumont, TX	12,150	48,600	12,150	72,900	1.05
Shell	Deer Park, TX	11,550	46,200	11,550	69,300	1.00
Union Carbide	Taft, LA	26,100	104,400	26,100	156,600	2.25
Total		140,100	571,340	140,960	852,400	
		Coal Derived				
Ashland	Catlettsburg, KY	35,000	42,000	10,500	87,500	1.26
	N. Tonawanda, NY	10,500	12,600	3,150	26,250	3.78
Bethlehem Steel	Sparrows Point, MD	3,500	4,200	1,050	8,750	0.13
Jones & Laughlin	Aliquippa, PA	7,500	9,000	2,250	18,750	0.27
U.S. Steel	Clairton, PA	27,500	33,000	8,250	68,750	0.99
	Geneva, UT	3,500	4,200	1,050	8,750	0.13
Total		87,500	105,000	26,250	218,750	
		Styrene By-Product				
American Hoechst	Baton Rouge, LA	470	28,200	7,050	35,720	0.51
Cos-Mar	Carville, LA	610	36,600	9,150	46,360	0.67
Dow	Freeport, TX	710	42,600	10,650	53,960	0.78
	Midland, MI	160	9,600	2,400	12,160	0.18
Gulf	Donaldsonville, LA	280	16,800	4,200	21,280	0.31
Monsanto[b]	Texas City, TX	197	11,842	2,961	15,000	0.22
Amoco[c]	Texas City, TX	42	2,526	632	3,200	0.05
Total		2,469	148,168	37,043	187,680	

*Based on 8760 hr/yr operation.

[a] See ref. 18

[b] See ref. 22

from the reactor and distillation vents. Storage emissions represent the loss from both working and final product storage as well as loading and handling losses. Fugitive emissions are those that result from plant equipment leaks.

Toluene emissions from catalytic reformate, pyrolysis gasoline, and coal-derived and styrene by-product were 794,300 lb, 852,400 lb, 218,750 lb, and 187,680 lb respectively in 1978.

Other associated emissions would primarily include benzene and the three xylene isomers.

Process emissions of toluene from refineries are apparently quite low because of the use of flares as hydrocarbon control devices.

B. USES

Toluene emissions from its use to produce benzene estimated to be 693,000 lb. The emissions are tabulated in Table 27-12 using the emission factors listed in Table 27-8.

Toluene emissions resulting from its use in toluene diisocyanate manufacture were estimated to have been 544,226 lb in 1978. Emissions are tabulated in Table 27-13.

Toluene emissions from all other chemical intermediate end-uses are tabulated in Table 27-14. Toluene emissions were 43,000 lb from benzyl chloride, 208,500 lb from benzoic acid, 43,200 lb from xylene disproportionation, 55,000 lb from vinyl toluene, 28,000 lb from p-cresol, and 27,000 lb from benzaldehyde. Emission factors used to estimate toluene emissions are listed in Table 27-8.

Other miscellaneous uses of toluene caused an estimated 20,140 lb of toluene emissions. This estimate was made by using an emission factor of 0.00038 lb toluene lost per lb used and was derived from a weighted average of all other toluene chemical intermediate end-uses.

For the purpose of this report all toluene used in paints and coatings, 578,000,000 lb, is assumed released to the atmosphere. Specific end-user locations are considered too widespread to identify regionally.

Table 27-12. Toluene Emissions from Benzene Producers

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
American Petrofina	Port Arthur, TX	6,550	13,100	6,550	26,200	0.38
	Big Spring, TX	11,400	22,800	11,400	45,600	0.66
Ashland Oil	Catlettsburg, KY	10,000	20,000	10,000	40,000	0.58
Costal States	Corpus Christi, TX	17,150	34,300	17,150	68,600	0.99
Commonwealth	Penuelas, PR	32,850	65,700	32,850	131,400	1.89
Crown	Pasadena, TX	6,550	13,100	6,550	26,200	0.38
Dow	Freeport, TX	7,150	14,300	7,150	28,600	0.41
Gulf	Alliance, LA	13,400	26,800	13,400	53,600	0.77
	Philadelphia, PA	5,700	11,400	5,700	22,800	0.33
Phillips	Guayama, PR	11,400	22,800	11,400	45,600	0.66
Quintana-Howell	Corpus Christi, TX	21,100	42,200	21,100	84,400	1.22
Shell	Odessa, TX	2,000	4,000	2,000	8,000	0.12
Sun	Corpus Christi, TX	5,700	11,400	5,700	22,800	0.33
	Toledo, OH	18,000	36,000	18,000	72,000	1.04
	Tulsa, OK	4,300	8,600	4,300	17,200	0.25
Total		173,250	346,500	173,250	693,000	

*Based on 8760 hr/yr operation.

Table 27-13. Toluene Emissions from Toluene Diisocyanate Producers

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
BASF Wyandotte [a]	Geismar, LA	107,244	44,536	26,366	178,146	2.56
Dow Chemical	Freeport, TX	42,350	17,600	10,450	70,400	1.01
DuPont	Deepwater, NJ	29,250	12,160	7,220	48,640	0.70
Mobay Chem. Corp.	Baytown, TX	54,670	22,720	13,490	90,880	1.31
Olin Corp.[b]	New Martinsville, WV	43,250	17,600	10,450	70,400	1.01
	Ashtabula, OH	12,320	5,120	3,040	20,480	0.29
Rubicon Chems. Inc.	Geismar, LA	16,940	7,040	4,180	28,160	0.41
Union Carbide	S. Charleston, WV	22,330	9,280	5,510	37,120	0.53
Total		327,464	136,056	80,706	544,226	

*Based on 8760 hr/yr operation.

[a] See ref. 19

[b] See ref. 20

Allied Chemical, Moundsville, WV does not emit toluene (ref. 21). Olin Corp, Lake Charles, LA facilities are no longer operating (ref. 20).

Table 27-14. Toluene Emissions from Other Chemical Intermediate Users

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		Benzyl Chloride Producers				
Monsanto	Bridgeport, NJ	19,800	10,800	5,400	36,000	0.518
Stauffer	Edison, NJ	3,300	1,800	900	6,000	0.086
UOP, Inc.	East Rutherford, NJ	550	300	150	1,000	0.014
Total		23,650	12,900	6,450	43,000	
		Benzoic Acid Producers				
Kalama	Kalama, WA	72,000	28,800	7,200	108,000	1.55
Velsicol	Beaumont, TX	26,000	10,400	2,600	39,000	0.56
	Chattanooga, TN	31,000	12,400	3,100	46,500	0.67
Pfizer	Terre Haute, IN	3,000	1,200	300	4,500	0.06
Tenneco	Garfield, NJ	7,000	2,800	700	10,500	0.15
Total		139,000	55,600	13,900	208,500	
		Xylene Disproportionation Producers				
ARCO	Houston, TX	5,300	10,600	5,300	21,200	0.31
Sun	Marcus Hook, PA	5,500	11,000	5,500	22,000	0.32
Total		10,500	21,600	10,800	43,200	

Table 27-14 (concluded)

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		Vinyl Toluene Producer				
Dow	Midland, MI	30,250	16,500	8,250	55,000	0.79
		p-Cresol Producer				
Sherwin Williams	Chicago, IL	16,800	7,000	4,200	28,000	0.40
		Benzaldehyde Producers				
Kalama	Kalama, WA	3,240	1,440	720	5,400	0.078
	Eddystone, PA	3,240	1,440	720	5,400	0.078
Stauffer	Edison, NJ	3,240	1,440	720	5,400	0.078
Tenneco	Garfield, NJ	3,240	1,440	720	5,400	0.078
UOP	E. Rutherford, NJ	3,240	1,440	720	5,400	0.078
Total		16,200	7,200	3,600	27,000	

*Based on 8760 hr/yr operation.

Hydroscience estimates that 15% of the toluene used in other solvent applications is consumed as a fuel. The remaining 247,000,000 lb of toluene is released to the atmosphere. Again, specific source/industry locations could not be identified because use is considered too widespread.

C. INCIDENTAL SOURCES

Since gasoline consumes 91% of all toluene produced, it is the largest source of toluene emissions.

There are three distinct toluene emission sources from gasoline use. They include evaporation from its use in automobiles, evaporation from gasoline marketing activities (bulk and service stations), and emissions from the exhaust of automobiles.

Toluene emissions are estimated to have been 38,492,000 lb from gasoline marketing activities using an emission factor of 0.004735 lb hydrocarbon lost per lb gasoline consumed[14] and assuming toluene is 1.26 wt%[15] of the hydrocarbon emission. In Table 27-15 the total emissions from gasoline marketing are distributed by the total number of service stations in each geographic region.[14]

Toluene emissions are estimated to have been 35,400,000 lb from automobile gasoline evaporation using an emission factor of 0.83 g/mile hydrocarbon evaporative loss.[16] Average mileage was assumed to be 14.7 mile/gal,[14] and toluene was assumed to be 1.26 wt% of the total hydrocarbon emission.

Toluene emissions in automobile exhaust were estimated to have been 1,300,147,000 lb using an emission factor of 3.2 g/mile[16] of hydrocarbons in the exhaust, 14.7 mile/gal mileage,[14] and assuming toluene constituted 12%[17] by weight of the exhaust emission.

Toluene emissions from coke ovens were estimated to have been 25,680,000 lb using an emission factor of 0.48 lb toluene lost per ton of coke produced and estimating coke production at 107 billion lb in 1978. Emissions are summarized and distributed in Table 27-16 by the number of coke oven sites in each region.[5]

Table 27-15. Toluene Emissions from Gasoline Marketing[a]

Region	Number of Sites	Toluene Emissions (lb/yr)
New England	11,105	1,887,850
Middle Atlantic	28,383	4,825,110
East North Central	42,270	7,185,900
West North Central	23,304	3,961,680
South Atlantic	37,286	6,338,620
East South Central	16,313	2,773,210
West South Central	28,336	4,817,120
Mountain	12,815	2,178,550
Pacific	26,647	4,529,900
Total	226,459	38,492,000[b]

[a] See ref. 13.

[b] Average toluene emission per site: 170 lb/yr (0.002 g/sec).

Table 27-16. Toluene Emissions from Coke Oven Operations[a]

Region	Number of Sites	Toluene Emissions (lb/yr)
New England	0	0
Middle Atlantic	15	6,314,775
East North Central	25	10,524,625
West North Central	3	1,262,955
South Atlantic	4	1,683,940
East South Central	9	3,788,865
West South Central	2	841,970
Mountain	2	841,970
Pacific	1	420,985
Total	61	25,680,000[b]

[a] See ref. 4.

[b] Average emissions: 420,985 lb/yr per site (6.06 g/sec).

Vent parameter data for both production and end-uses of toluene are summarized in Table 27-17.

The total nationwide emissions of toluene are estimated to be 2,229,434,200 lb. Total emissions are summarized in Table 27-18.

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Table 27-17. Toluene Vent Parameter Data*

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Production - catalytic reformate						
Process	11	54	3.0	300	12	
Storage	12	30	0.33	80		
Fugitive						800 X 1400
Production - pyrolysis gasoline						
Process	4	250	2.50	100	210	
Storage	10	30	0.17	80		
Fugitive						600 X 1200
Production - coal derived						
Process	2	60	1.5	120	40	
Storage	8	24	0.25	80		
Fugitive						400 X 400
Production - styrene by-product						
Process	3	200	0.25	115	5	
Storage	4	30	0.17	80		
Fugitive						200 X 700
Benzene production						
Process	4	50	0.25	95	16	
Storage	8	55	4.0	115		
Fugitive						300 X 600
TDI production						
Process	2	90	0.90	110	40	
Storage	6	24	0.17	80		
Fugitive						300 X 500
Benzoic acid production						
Process	2	50	1.25	110	15	
Storage	5	24	0.25	80		
Fugitive						300 X 300
Benzyl chloride production						
Process	2	38	1.0	78	0.02	
Storage	4	24	0.17	70		
Fugitive						300 X 300

Table 27-17 (concluded)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft X ft)
Vinyl toluene production						
Process	2	50	1.0	120	15	
Storage	4	24	0.17	80		
Fugitive						100 X 100
Benzaldehyde production						
Process	1	40	0.75	125	10	
Storage	3	20	0.17	80		
Fugitive						100 X 100
p-Cresol production						
Process	2	30	1	208	75	
Storage	4	24	0.17	80		
Fugitive						200 X 200
Xylene production						
Process	3	60	1.5	150	60	
Storage	4	30	0.25	80		
Fugitive						300 X 600
Coke ovens						
Process	2	30	1	300	15	

*Building cross-section:
Benzoic acid - 50 m^2
Benzyl chloride - 50 m^2
Vinyl toluene - 20 m^2
Benzaldehyde - 50 m^2
All others - 200 m^2

Table 27-18. Total Nationwide 1978 Toluene Emissions

Source	Toluene Emissions (lb/yr)
Toluene production - catalytic reformate	794,300
Toluene production - pyrolysis gasoline	852,400
Toluene production - coal-derived	218,750
Toluene production - styrene by-product	187,680
Paint and coatings solvent	579,000,000
Adhesives, inks, pharmaceutical solvent	247,000,000
Benzene production	693,000
Toluene diisocyanate production	544,226
Benzoic acid production	208,500
Benzyl chloride production	43,000
Vinyl toluene production	55,000
Benzaldehyde production	27,000
p-Cresol production	28,000
Xylene disproportionation production	43,200
Other/miscellaneous uses	20,140
Gasoline - marketing evaporative loss	38,492,000
Gasoline - automobile evaporative loss	35,400,000
Gasoline - automobile exhaust emissions	1,300,147,000
Coke ovens	25,680,000
Total	2,229,434,200

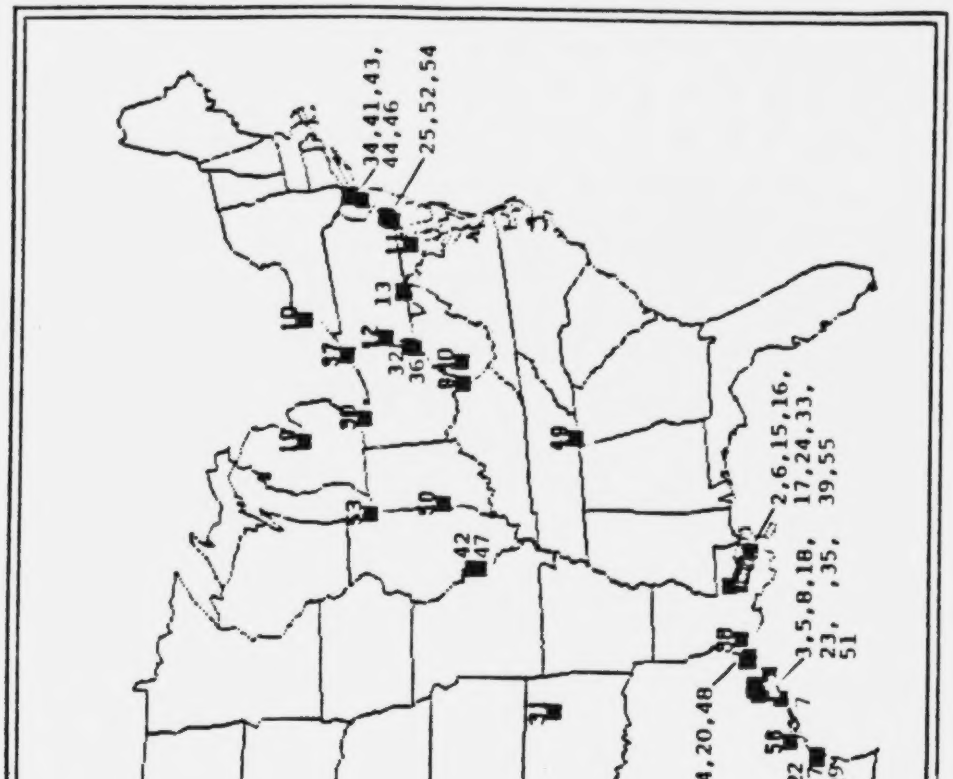
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FIGURE 27-1. SPECIFIC POINT SOURCES OF TOLUENE EMISSIONS

Table 27-19. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF TOLUENE

NO.[a]	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ARCO	CHANNELVIEW, TX	29 50 04	095 06 43	12906	1	1	0	0.015728	0.012399
2	EXXON	BATON ROUGE, LA	30 09 10	090 54 20	13970	1	1	0.218164	0.872650	0.218163
3	GULF	CEDAR BAYOU, TX	29 49 29	094 55 10	12923	1	1	0.408168	1.633050	0.408232
4	MOBILE	BEAUMONT, TX	30 04 14	094 03 40	12917	1	1	0.174912	0.699840	0.174943
5	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	1	1	0.166288	0.665270	0.166318
6	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	1	1	0.375824	1.503360	0.375824
7	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	2	1	0.354260	1.416790	0.354230
							3	0.010179	0.613440	0.153349
							4	0.102992	0.205984	0.102962
							5	0.609842	0.253422	0.150495
8	MONSANTO	TEXAS CITY, TX	29 22 45	094 33 30	12923	6	3	0.002834	0.170327	0.042589
9	ASHLAND	CATLETTSBURG, KY	38 22 39	082 55 58	13866	4	2	0.503996	0.604008	0.151192
							4	0.143964	0.287928	0.143994
10	ASHLAND	N. TONAWANDA, NY	42 59 45	078 55 27	14747	5	2	0.151192	0.181376	0.453577
11	BETHLEHEM STEEL	SPARROW POINT, MD	39 18 30	076 34 30	13701	5	2	0.050356	0.060376	0.015126
12	JONES LAUGIDLI	ALIQUIPPA, PA	40 35 54	080 14 24	14762	5	2	0.108004	0.129632	0.032407
13	U. S. STEEL	CLAIRTON, PA	40 18 15	079 52 43	14762	5	2	0.395992	0.475136	0.118785
14	U. S. STEEL	GENEVA, UT	40 19 01	111 44 29	24101	5	2	0.050356	0.060376	0.015126
15	AMER HOECHST	BATON ROUGE, LA	30 33 02	091 15 50	13970	6	3	0.006753	0.406012	0.101503
16	COS-MAR	CARVILLE, LA	30 13 30	091 04 00	13970	6	3	0.008751	0.527016	0.131754
17	GULF	DONALDSONVILLE, LA	30 13 30	091 04 00	13970	6	3	0.003996	0.241884	0.060471
18	AMOCO	TEXAS CITY, TX	29 21 40	094 55 50	12906	6	3	0.000604	0.036332	0.009090

Table 27-19. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF TOLUENE (continued)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
19	DOW	MIDLAND, MI	43 35 28	084 13 08	14845	7	3	0.002283	0.138256	0.034532
							8	0.435566	0.237568	0.118880
20	AMER PETROFINA	PORT ARTHUR, TX	29 57 30	093 53 20	12917	8	4	0.094368	0.188736	0.094305
21	AMER PETROFINA	BIG SPRING, TX	32 17 10	101 25 17	13962	8	4	0.164128	0.328256	0.164162
22	COASTAL STATES	CORPUS CRISTI, TX	27 48 43	097 26 28	12925	8	4	0.246956	0.493912	0.246956
23	CROWN OIL	PASADENA, TX	29 44 40	095 10 30	12906	8	4	0.094240	0.188480	0.094305
24	GULF	ALLIANCE,LA	29 50 00	090 00 19	12958	8	4	0.192924	0.385848	0.192954
25	GULF	PHILADELPHIA, PA	39 54 00	075 12 30	13739	8	4	0.082064	0.164128	0.082065
27	QUINTANT-HOWELL	CORPUS CRISTI, TX	27 48 35	097 27 30	12925	8	4	0.303780	0.607560	0.303843
28	SHELL	ODESSA, TX	31 49 14	102 19 53	23023	8	4	0.028792	0.057584	0.028792
29	SUN OIL	CORPUS CRISTI, TX	27 50 00	097 31 25	12925	8	4	0.082064	0.164128	0.082064
30	SUN OIL	TOLEDO, OH	41 36 52	083 31 40	94830	8	4	0.259260	0.518520	0.259196
31	SUN OIL	TULSA, OK	36 08 18	096 01 18	13968	8	4	0.061896	0.123792	0.061929
32	BASF WYANDOTTE	GEISMAR, LA	30 11 34	091 00 42	13970	9	5	1.541412	0.640602	0.380391
33	DUPONT	DEEPWATER, NJ	39 41 25	075 30 35	13739	9	5	0.421360	0.175038	0.103976
34	MOBAY CHEM CORP	BAYTOWN, TX	29 45 30	094 54 25	12906	9	5	0.787290	0.327054	0.194254
35	MOBAY CHEM CORP	NEW MARTINSVILLE, WV	39 44 50	080 50 50	13736	9	5	0.622780	0.253422	0.150495
36	OLIN CORP	ASHTABULA, OH	41 53 07	080 45 50	14843	9	5	0.177384	0.073818	0.043760
37	RUBICON CHEMS	GEISMAR, LA	30 12 00	091 11 30	12958	9	5	0.243912	0.101406	0.060185
38	UNION CARBIDE	SO CHARLESTON, WV	38 19 35	081 40 29	13866	9	5	0.321538	0.133560	0.079338

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Table 27-19. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF TOLUENE (concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
39	MONSANTO	BRIDGEPORT,NJ	39 47 33	075 23 45	13739	10	7	0.285134	0.155504	0.077752
41	STAUFFER	EDISON, NJ	40 29 23	074 23 03	94741	11	7	0.047502	0.025876	0.012969
42	UOP INC	RUTHERFORD, NJ	40 49 46	074 05 30	94741	11	9	0.046645	0.020739	0.010369
							7	0.007928	0.004312	0.002156
43	KALAMA	KALAMA, WA	46 00 54	122 51 05	24229	12	9	0.046645	0.020739	0.010369
							6	1.036784	0.414765	0.103691
44	TENNECO	GARFIELD, NJ	40 52 28	074 06 47	94741	12	9	0.046645	0.020739	0.010369
							6	0.100838	0.040270	0.010084
							9	0.046645	0.020739	0.010369
46	VELSICOL	BEAUMONT, TX	29 58 16	094 03 17	12917	13	6	0.037443	0.149830	0.037418
47	VELSICOL	CHATTANOOGA, TN	35 02 31	085 16 86	13882	13	6	0.446348	0.178525	0.044647
48	PFIZER	TERRA HAUTE, IN	39 26 01	087 24 22	93819	13	6	0.043188	0.017280	0.004313
49	ARCO	HOUSTON, TX	29 42 17	095 16 01	12960	14	11	0.076293	0.152716	0.076325
50	SUN	MARCUS HOOK, PA	39 48 45	075 24 51	13739	14	11	0.079149	0.158424	0.079179
51	SHERWIN WILLIAM	CHICAGO, IL	41 43 04	087 36 30	94846	15	10	0.241882	0.100836	0.060407
52	KALAMA	EDDYSTONE, PA	39 50 58	075 20 00	13739	16	9	0.046645	0.020739	0.010369
53	DUPONT	LAPLACE,LA	30 04 00	090 32 00	12958	17	12	8.464614	0.097540	1.219685
54	DUPONT	VICTORIA, TX	28 40 29	096 57 21	12923	17	12	2.693304	0.031076	0.388064

[a] Some emission plants have been eliminated due to comments to early drafts of this document.

TABLE 27-19 (Continued)

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* Plant types:

Type 1: Plant produces toluene (gasoline pyrolysis)
Type 2: Plant produces toluene (gasoline pyrolysis and from styrene production, benzene, and toluene diisocyanate
Type 3: Plant produces toluene (gasoline pyrolysis and from styrene production)
Type 4: Plant produces toluene (coal derived) and benzene
Type 5: Plant produces toluene (coal derived)
Type 6: Plant produces toluene (from styrene production)
Type 7: Plant produces toluene (from styrene production) and vinyl toluene
Type 8: Plant produces benzene
Type 9: Plant produces toluene diisocyanate
Type 10: Plant produces benzylchloride
Type 11: Plant produces benzyl chloride and benzaldehyde
Type 12: Plant produces benzoicacid and benzaldehyde
Type 13: Plant produces benzoic acid
Type 14: Plant produces oxylene
Type 15: Plant produces p-cresol
Type 16: Plant produces benzaldehyde
Type 17: Plant produces chloroprene

† Source types:

Type 1: Toluene production (gasoline pyrolysis)
Type 2: Toluene production (coal derived)
Type 3: Toluene production (styrene production)
Type 4: Benzene production
Type 5: Toluene diisocyanate production

TABLE 27-19 (Concluded)

Type 6: Benzoic acid production
Type 7: Benzyl chloride production
Type 8: Vinyl toluene production
Type 9: Benzaldehyde production
Type 10: p-cresol production
Type 11: Xylene disproportionation
Type 12: Chloroprene production

Table 27-20. EXPOSURE AND DOSAGE OF TOLUENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) . persons]
25	7	178
10	345	4,590
5	1,296	10,800
2.5	5,809	27,200
1	23,516	54,700
0.5	59,628	79,700
0.25	159,488	114,000
0.1	496,875	165,000
0.05	1,305,009	219,000
0.025	3,176,495	284,000
0.01	8,480,952	367,000
0.005	14,708,444	410,000
0.0025	23,466,299	441,000
6.59×10^{-5}	30,919,980	454,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 27-21. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF TOLUENE

Region	Toluene Production (Catalytic Reforming)*		Gasoline Marketing		Coke Oven	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0	0	0.00245	11,105	6.062	0
Middle Atlantic	0.535	17	0.00245	28,383	6.062	15
East North Central	0.510	28	0.00245	42,270	6.062	25
West North Central	0.227	16	0.00245	23,304	6.062	3
South Atlantic	0.250	5	0.00245	37,286	6.062	4
East South Central	0.422	8	0.00245	16,313	6.062	9
West South Central	0.634	71	0.00245	28,336	6.062	2
Mountain	0.116	23	0.00245	12,815	6.062	2
Pacific	0.429	33	0.00245	26,647	6.062	1

---

* This includes both the nonisolated toluene (as BTX) producers and the isolated toluene producers.

TABLE 27-22. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF TOLUENE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)				Dosage [$10^6(\mu g/m^3) \cdot$ persons]			
	Toluene Production	Gasoline Marketing	Coke Oven	U.S. Total	Toluene Production	Gasoline Marketing	Coke Oven	U.S. Total
100	0	0	2.1	2.1	0	0	0.29	0.29
50	0	0	12	12	0	0	0.98	0.98
25	0	0	38	38	0	0	1.83	1.8
10	1.3	0	130	131	0.02	0	3.2	3.2
5	15	0	310	325	0.11	0	4.4	4.5
2.5	55	0	874	928	0.22	0	6.4	6.6
1	207	0	2,560	2,770	0.47	0	8.9	9.4
0.5	--	--	--	--	0.67	0	10.3	11
0.25	--	--	--	--	0.99	0	12	13
0.1	--	--	--	--	1.5	0.1	14	16
0.05	--	--	--	--	1.8	0.7	16	19
0.025	--	--	--	--	2.1	1.7	18	21
0.01	--	--	--	--	2.6	3.4	18	24
0	--	--	--	--	2.9	4.7	18	48

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 27-23. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF TOLUENE

Parameter	Value
Daytime decay rate (K_d)	2.8 x 10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	11,895 gm/sec
Paint/coating solvent emissions	8,337.6 gm/sec
Adhesive/links solvent emissions	3,556.8 gm/sec
Miscellaneous	0.3 gm/sec
Nationwide mobile source emissions (E_M)	19,232 gm/sec
Motor vehicle evaporation loss	509.8 gm/sec
Motor vehicle exhaust loss	18,722.2 gm/sec
Ratio of truck emissions to auto emissions	0

TABLE 27-24. TOLUENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

Expo Level ($\mu g/m^3$)	Population (person)	Dosage ($\mu g/m^3$/ person)	Percentage of Contribution			Percentage of Distribution		
			Heating	Stationary	Mobile	City Type 1	City Type 2	City Type 3
100.000000	58188	7185433.1	0.	42.3	57.7	100.0	0.	0.
50.000000	505140	50335701.2	0.	63.3	36.7	100.0	0.	0.
25.000000	12853644	460475519.4	0.	61.5	38.5	100.0	0.	0.
10.000000	55332557	1141494655.0	0.	50.4	49.6	98.1	.9	1.0
5.000000	123701326	1623319075.5	0.	48.5	51.5	94.2	3.0	2.7
0.	158679135	1742401236.9	0.	47.9	52.1	91.1	3.4	5.5

TABLE 27-25. EXPOSURE AND DOSAGE SUMMARY OF TOLUENE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) . persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
100	0	2,100	58,347	60,447	0	290,000	7,185,433	7,475,493
50	0	12,000	505,140	517,140	0	980,000	50,335,701	51,315,701
25	7	38,000	12,853,644	12,891,644	178	1,800,000	460,475,519	462,275,697
10	345	131,000	55,332,557	55,463,902	4,590	3,200,000	1,141,494,655	1,144,699,245
5	1,296	325,000	123,701,326	--	10,800	4,500,000	1,623,319,075	--
2.5	5,809	928,000	--	--	27,200	6,600,000	--	--
1	23,516	2,770,000	--	--	54,700	9,400,000	--	--
0.5	59,628	--	--	--	79,700	11,000,000	--	--
0.25	159,488	--	--	--	114,000	13,000,000	--	--
0.10	496,875	--	--	--	165,000	16,000,000	--	--
0.59 x 10^{-5}	30,919,980	--	158,679,135	158,679,135	454,000	48,000,000	1,742,401,000	1,790,855,000

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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APPENDIX A-28 ----- Trichloroethylene

TRICHLOROETHYLENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 79-01-6

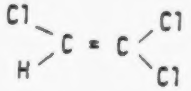
Synonyms: Ethylene Trichloride; Trichloroethene; Ethinyl Trichloride; Acetylene Trichloride; Tri-Clene; Trielene; Trilene; Trichloran; Trichloren; Chlorylen; Gemalgene; Algylen Trimar; Triline; Tri; Trethylene; Sestrosol; Germalgene

Chemical Formula

Molecular Weight: 131.39

Molecular Formula: C_2HCl_3

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid-nonflammable, mobile, chloroform-like odor

Boiling Point: 87°C at 760 mm

Melting Point: -73°C

Density: 1.4642 at 20°C/4°C

Vapor Pressure: 77.5 mm at 25°C

Vapor Density: 4.53

Solubility: Slightly soluble (1.1 g/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.29

Atmospheric Reactivity

Transformation Products: Phosgene, HCl, CO, Trichloroethylene oxide, and Dichloroacetylchloride from oxidation by O_3 & RO_2. Formyl Chloride
Reactivity Toward OH·: quite reactive, 1/3 x vinyl chloride, 0.2 x propene

Reactivity Toward O_3: slow oxidation

Reactivity Toward Photolysis: 0

Major Atmospheric Precursors: N/A

Formation Reactivity: Not Applicable

I. SOURCES

Trichloroethylene, $CHCl=CCl_2$, is currently produced in the United States by processes involving either chlorination or oxychlorination of ethylene dichloride or other C_2 chlorinated hydrocarbons. Perchloroethylene is a coproduct of the reaction. Feed adjustments can vary product ratios from all perchloroethylene to nearly all trichloroethylene. Until early 1978 trichloroethylene was also produced by acetylene chlorination, but that process was abandoned in early 1978 due to its high manufacturing cost.[1]

Only three companies currently produce trichloroethylene in the United States. The locations of the plants and the 1978 capacity and estimated production level for each plant are shown in Table 28-1.[1,2,3] An estimated 290 million pounds of trichloroethylene was produced in 1978.[2]

The largest end-use of trichloroethylene is in the industrial metal fabricating industry for vapor degreasing and cleaning operations. This end-use consumed an estimated 80% of production in 1978 amounting to 232 million pounds. Of this total, 195.6 million pounds was used in degreasers and 36.4 million pounds was used in cold cleaners.

Most other applications of trichloroethylene are small and minor in importance when compared to degreasing use. Other applications include its use as a solvent or solvent base for adhesives, sealants, lubricants, and dip-painting processes. Total consumption for this broad category is estimated to have been 11.6 million pounds (4%) in 1978. Exports of trichloroethylene are estimated to have been 46.4 million pounds (16%) in 1978. End-uses are summarized in Table 28-2.[2]

II. EMISSION ESTIMATES

A. PRODUCTION

Estimated production losses are shown in Table 28-3 for each of the three producing locations.[4,5,6] Total emissions of trichloroethylene resulting from its production are estimated to have been 735,200 pounds in 1978. Process emissions originate primarily from the condenser vent off the oxychlorination reactor and the

Table 28-1. Production of Trichloroethylene [a]

Source [b]	Location	1978 Estimated Production (million pounds) [c]	1978 Estimated Capacity (million pounds)	Geographic Coordinates
Dow Chemical	✓Freeport, TX	89.0	120	28°, 59', 15" N. Latitude 95°, 24', 45" W. Longitude
Ethyl Corporation	✓Baton Rouge, LA	37.0	50	30°, 18', 00" N. Latitude 91°, 08', 00" W. Longitude
PPG Industries	✓Lake Charles, LA	164.0	220	30°, 13', 14" N. Latitude 93°, 16', 54" W. Longitude
Total		290	390	

[a] See refs. 1—3.

[b] Diamond Shamrock Corporation placed a 50 million pound per year unit at Deer Park, Texas, on standby in early 1978. Hooker Chemical Company no longer produces trichloroethylene at its Taft, LA, facility.

[c] The distribution of production for each producer is determined by the ratio of total U.S. production/total capacity as compared to individual capacity.

Table 28-2. Trichloroethylene End-Uses 1978*

End Use	% of Total Consumption	End-Use Consumption (M lb)
Vapor degreasing	80	232
Solvent	4	11.6
Export	16	46.4
Total	100	290

*See refs. 1 and 2.

condenser vent off the light-ends column. Storage emissions represent the losses from both working and final product storage tanks as well as loading and handling losses. Fugitive emissions are those emissions caused by leaks from plant equipment. Vent stack data are shown in Table 28-4. normally four process and nine storage tank vents are involved.

B. USES

For the purpose of this report, emissions resulting from the export of trichloroethylene are assumed to be negligible. The total amount, 11,600,000 pounds, of trichloroethylene used in solvent and solvent-based applications is eventually released to the atmosphere. Statistical data on individual solvent use by specific category are not available and are usually estimated as a group by difference. Therefore, no point sources or model sources were identified. Trichloroethylene vapor degreasing emissions are estimated to have been 228.5 million pounds in 1978, or 98.5% of the total amount of trichloroethylene consumed for this end-use. An estimated 9.5% of the trichloroethylene used in cold cleaners is encapsulated or burned and is not released to the atmosphere.[7] An estimated 15% of the trichloroethylene used in degreasing applications was used in cold cleaning equipment. The remaining 85% was used in open top or conveyorized degreasers. The average emission rates per unit and the total number of units in operation nationally are shown in Table 28-5. The estimated number of degreasers using trichloroethylene in 1978 by geographic area is shown in Table 28-6.

Total nationwide emissions of trichloroethylene in 1978 are estimated to have been 240.8 million pounds. A tabulation of the losses is shown in Table 28-7.

Table 28-3. 1978 Trichloroethylene Production Emissions[a]

Company	Location	1978 Production (lb X 10^6)	Process Emissions (lb X 10^4)	Storage Emissions (lb X 10^4)	Fugitive Emissions (lb X 10^4)	Total Emissions (lb X 10^4)[b]	Total Emissions (gr/sec)[c]
Dow[d]	Freeport, TX	89	7.88	12.45	11.54	31.87	4.59
PPG	Lake Charles, LA	164	8.40	13.28	12.30	33.98	4.89
Ethyl	Baton Rouge, LA	37	1.89	3.00	2.78	7.67	1.103
Total		290	18.17	28.73	26.62	73.52	10.58

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[a] See refs. 4--6.

[b] Emission factor trichloroethylene (lb trichloroethylene lost/lb trichloroethylene produced)

Process	.000512	B - (derived from state air emission files)
Storage	.000810	B - (derived from state air emission files)
Fugitive	.000750	D - (derived from engineering estimate)
Total	.002072	

Fugitive emissions are released over a 300 x 300 ft area.

[c] 8760 operating hours per year, i.e., 24 hr/day, 7 days/ wk, 52 wk/yr.

[d] See ref. 9

Table 28-4. Trichloroethylene Vent Parameters

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)
Production[a]	-				
Process vent	4	45	0.17	-10—150	5.5
Storage	9	20	0.17	70	
Use[b]					
Cold cleaner	1	15	0.5	70	
Vapor degreaser	1	15	0.5	150	

[a] Building cross-section - 5M^2.

[b] Building cross-section - 50M^2.

Table 28-5. Trichloroethylene Emissions from Solvent Degreasers

Type Degreaser	Estimated National Emission (M̄ lb/yr)	Estimated Number of Units in Service	Average Emission Rate Per Unit[a]	
			(lb/yr)	(gm/sec)[b]
Cold cleaners	32.9	49,773	661	0.04
Open top vapor degreasers	122.25	6,110	20,000	1.12
Conveyorized degreasers	73.35	1,232	59,500	3.33
Total	228.5	57,115		
Weighted Average			4,000	0.22

[a] See ref. 7.

[b] The number of annual operating hr was assumed to be 2,250 hr.

Table 28-6. Estimated Number of Degreasers Using Trichloroethylene in 1978 by Geographic Location*

Degreaser Type	North East	Mid Atlantic	East North-Central	West North-Central	South Atlantic	East South-Central	West South-Central	Mountain	Pacific	TOTAL
Cold cleaners	2,991	7,760	13,179	4,362	6,005	2,944	4,832	1,806	5,893	49,773
Open top vapor degreasers	560	1,158	1,742	452	465	265	398	174	896	6,110
Closed conveyorized degreasers	113	244	405	80	84	52	68	21	165	1,232

*See ref. 8.

Table 28-7. Estimated 1978 Trichloroethylene Nationwide Emission Losses

Source	Estimated National Emission (million lb/yr)
Production	0.7
Cold cleaners	32.9
Vapor degreasers	195.6
Solvent	11.6
Export	0
Total	240.8

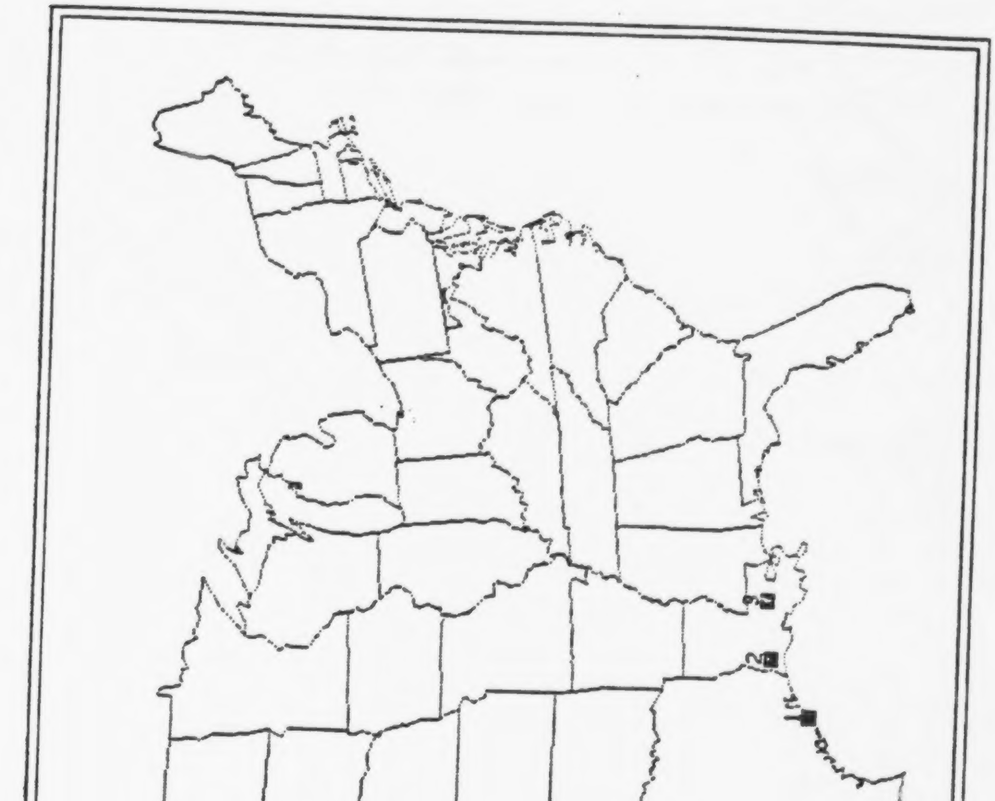

FIGURE 28-1. SPECIFIC POINT SOURCES OF TRICHLOROETHYLENE EMISSIONS

Table 28-8. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF TRICHLOROETHYLENE

No.	Company	Site	Latitude	Longitude	Star Station	Plant Type	Source Type	EMISSIONS (GM/SEC) Process	Storage	Fugitive
1	Dow	Freeport, TX	28 59 30	095 23 35	12923	1	1	1.132959	1.791349	1.659659
2	PPG	Lake Charles, LA	30 13 14	093 16 54	03937	1	1	1.209602	1.912322	1.771214
3	Ethyl	Baton Rouge, LA	30 18 00	091 08 00	13970	1	1	.272159	.432014	.400304

TABLE 28-9. EXPOSURE AND DOSAGE OF TRICHLOROETHYLENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed[*] (persons)	Dosage [(ug/m^3) . persons]
25	2	72
10	20	318
5	112	899
2.5	425	1,880
1	3,341	6,440
0.5	9,169	10,600
0.25	37,129	20,400
0.1	87,317	28,300
0.05	171,976	34,100
0.025	232,333	36,500
0.00264[†]	451,451	38,900

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[*] People exposed to annual average concentrations equal to, or greater than, noted level.

[†] The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 28-10. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF TRICHLOROETHYLENE

Region	Cold Cleaning		Open Top Vapor Degreasing (OTVD)		Conveyorized Vapor Degreasing (CVD)	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.00952	2,991	0.288	560	0.857	113
Middle Atlantic	0.00952	7,760	0.288	1,158	0.857	244
East North Central	0.00952	13,179	0.288	1,742	0.857	405
West North Central	0.00952	4,362	0.288	452	0.857	80
South Atlantic	0.00952	6,005	0.288	465	0.857	84
East South Central	0.00952	2,944	0.288	265	0.857	52
West South Central	0.00952	4,832	0.288	398	0.857	68
Mountain	0.00952	1,806	0.288	174	0.857	21
Pacific	0.00952	5,893	0.288	896	0.857	165

TABLE 28-11. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF TRICHLOROETHYLENE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)				Dosage [$10^6(\mu g/m^3)$ • persons]			
	Cold Cleaning	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total	Cold Cleaning	Open Top Vapor Degreasing	Conveyorized Vapor Degreasing	U.S. Total
5	0	361	518	879	0	2.6	5.1	7.7
2.5	0	1,430	1,140	2,570	0	6.1	7.3	13
1	0	4,570	4,020	8,590	0	11	11.7	23
0.5	0	11,900	10,000	21,900	0	16	15.8	32
0.25	--	--	--	--	0.02	22	20.4	42
0.1	--	--	--	--	1.28	32	27.1	60
0.05	--	--	--	--	2.34	41	31	74
0.025	--	--	--	--	3.45	47	37	87
0.01	--	--	--	--	5.25	58	43	106
0	--	--	--	--	22.2	82	50	154

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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TABLE 28-12. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF TRICHLOROETHYLENE

Parameter	Value
Daytime decay rate (K_d)	2.8×10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	167.04 gm/sec
Nationwide mobile source emissions (E_M)	0

TABLE 28-13. TRICHLOROETHYLENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
.500000	505140	447676.0	0.	100.0	0.	100.0	0.	0.
.250000	9149730	3334007.3	0.	100.0	0.	100.0	0.	0.
.100000	27819254	6037914.6	0.	100.0	0.	100.0	0.	0.
.050000	73308971	9089292.7	0.	100.0	0.	98.0	.7	1.3
.025000	128273558	11194278.7	0.	100.0	0.	95.1	2.3	2.6
0.	158679135	11720159.7	0.	100.0	0.	92.7	2.7	4.6

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TABLE 28-14. EXPOSURE AND DOSAGE SUMMARY OF TRICHLOROETHYLENE

Concentration Level (ug/m3)	Population Exposed (persons) Specific Point Source	General Point Source	Area Source	U.S. Total	Dosage [(ug/m3) - persons] Specific Point Source	General Point Source	Area Source	U.S. Total
25	2	0	0	2	72	0	0	72
10	20	0	0	20	318	0	0	318
5	112	879,000	0	879,112	899	7,700,000	0	7,700,899
2.5	425	2,570,000	0	2,570,425	1,880	13,000,000	0	13,001,880
1	3,341	8,590,000	0	8,593,341	6,440	23,000,000	0	23,006,440
0.5	9,169	21,900,000	505,140	22,414,309	10,600	32,000,000	447,676	32,458,276
0.25	37,129	--	9,149,730	--	20,400	42,000,000	3,334,007	45,354,407
0.1	87,317	--	27,819,254	--	28,300	61,000,000	6,037,914	67,066,214
0.05	171,976	--	73,308,971	--	34,100	74,000,000	9,089,292	75,123,392
0.025	232,333	--	128,273,558	--	36,500	87,000,000	11,194,278	98,230,778
0.01	--	--	--	--	--	--	--	
0	451,451	--	158,679,135	--	38,500	154,000,000	11,720,159	165,759,059

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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7. Control of Volatile Organic Emissions from Solvent Metal Cleaning, EPA-450/2-77/022 (OAQPS No. 1.2-079), Research Triangle Park, NC (November 1977).

8. Solvent Metal Cleaning, Background Information: Proposed Standards (draft), EPA, NSPS, ESED Research Triangle Park, NC (November 1978).

9. Dow Chemical U.S.A., (Paul J. Sienknecht), Personal Communication in response to publication of the first draft of this report (June 1981).

APPENDIX A-29 ----- Xylene

m-XYLENE (PREDOMINANT OF 3 ISOMERS) CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 108-38-3

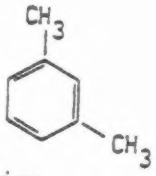
Synonyms: m-Xylol; Dimethybenzene

Chemical Formula

Molecular Weight: 106.2

Molecular Formula: C_8H_{10}

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - mobile, flammable, colorless

Boiling Point: 139°C at 760 mm

Melting Point: -47.4°C

Density: 0.864 at 20°C/4°C

Vapor Pressure: 8.56 mm at 25°C

Vapor Density: 3.66

Solubility: Nearly insoluble (0.13 gm/l of H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.20

Atmospheric Reactivity

Transformation Products: Organic aerosol, formaldehyde, acetaldehyde, PAN, benzaldehyde. Xylene can be easily chlorinated, sulfonated, or nitrated.

Reactivity Toward OH·: t 1/2 = 8 x Butane

Reactivity Toward O_3: No Reaction

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

p-XYLENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 106-42-3

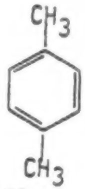
Synonyms: p-Xylol; Dimethybenzene

Chemical Formula

Molecular Weight: 106.2

Molecular Formula: C_8H_{10}

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless (plates or prisms at low temperatures)

Boiling Point: 138.5°C at 160 mm

Melting Point: 13.2°C

Density: 0.8611 at 20°C/4°C

Vapor Pressure: 10 mm at 27.3°C

Vapor Density: 3.66

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 3.15

Atmospheric Reactivity

Transformation Products: Reacts with oxidizing materials (see m-Xylene for products)

Reactivity Toward OH·: t 1/2 = 3 days, 8 x Butane
Reactivity Toward O_3: t 1/2 = 100 yr
} same as toluene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

o-XYLENE CHEMICAL DATA

Nomenclature

Chemical Abstract Service Registry Number: 95-47-6

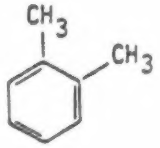
Synonyms: o-Xylol; Dimethybenzene

Chemical Formula

Molecular Weight: 106.2

Molecular Formula: C_8H_{10}

Molecular Structure:



Chemical and Physical Properties

Physical State at STP: Liquid - colorless

Boiling Point: 144.4°C at 760 mm

Melting Point: -25°C

Density: 0.880 at 20°C/4°C

Vapor Pressure: 10 mm at 32.1°C

Vapor Density:

Solubility: Insoluble (H_2O)

Log Partition Coefficient (Octanol/H_2O): 2.77

Atmospheric Reactivity

Transformation Products: Reacts with oxidizing materials (see m-Xylene monograph for products)
Reactivity Toward OH·: 1/2 x m-Xylene

Reactivity Toward O_3: 1/2 x m-Xylene

Reactivity Toward Photolysis: NAPP

Major Atmospheric Precursors: N/A

Formation Reactivity:

I. SOURCES

A. PRODUCTION

The xylene isomers include para-xylene (p-xylene), ortho-xylene (o-xylene), and meta-xylene (m-xylene). Most of the xylene isomers produced occur together as mixed xylenes in an aromatic mixture (BTX) along with benzene and toluene. The majority of mixed xylenes currently are produced in the United States by catalytic reforming of petroleum. They are also obtained from pyrolysis gasoline as a by-product of olefin manufacture during the cracking of hydrocarbons. Small amounts of mixed xylenes as BTX are also obtained from coal-derived coke oven light oil and from the disproportionation of toluene.[1,2]

Approximately 8,555 million lb of mixed xylenes was isolated in 1978 from a total of 77,973 million lb of mixed xylenes produced as BTX. The isolated mixed xylenes are used primarily for the production of the individual isomers and for solvent applications. The nonisolated mixed xylenes as BTX are blended into gasoline.[1,2]

The largest source of mixed xylenes is from catalytic reformate. Catalytic reforming involves the hydrogenation of naphtha fractions that are unsatisfactory for use as gasolines. The aromatic fractions, consisting primarily of benzene, toluene, and mixed xylenes, are isolated from the reformate by a combination of extraction and distillation. Total mixed xylene produced from this source is estimated to have been 76,916 million lb with 7,991 million lb isolated for chemical use.[1,2]

The second largest source of mixed xylenes is from pyrolysis gasoline. An estimated 826 million lb of mixed xylene as BTX was produced from this source with an estimated 429 million lb isolated for chemical use.

The disproportionation of toluene produced an estimated 198 million lb of mixed xylenes of which 106 million lb was separated for chemical use.

Approximately 33 million lb of mixed xylene was produced from coal-derived BTX with an estimated 29 million lb separated for chemical use.

A summary of both isolated and nonisolated mixed xylenes production by source for 1978 is shown in Table 29-1.

There are currently 201 locations that produce mixed xylenes from catalytic reformate. They are shown in Table 29-2 by geographic region.[3] Of this total, only 29 plants isolate mixed xylenes from catalytic reformate. Three of the sites are located outside the continental United States and were not considered in this project scope. The locations of the plants, the mixed xylenes capacity, and the isolated mixed xylenes produced are shown in Table 29-3.

There are currently nine producers at nine locations that produce mixed xylene as BTX from pyrolysis gasoline manufacture. One of these sites is located in Puerto Rico and was considered outside the project scope. The locations of the plants, the ethylene capacity, the estimated mixed xylene production as BTX and as isolated mixed xylene, and the total mixed xylene produced are shown in Table 29-4.

The three locations that produce coal-derived mixed xylenes and the two sites that produce mixed xylenes from toluene disproportionation are also listed in Table 29-4.

Since the individual isomers are actually end-uses of mixed xylene production, they will be discussed in the uses section of this report.

B. USES

The end-use distribution of mixed xylenes is shown in Table 29-5. All mixed xylenes produced as BTX and not isolated (69,418 million lb) are blended into gasoline. The remaining isolated mixed xylenes (8,555 million lb) are used to produce the individual xylene isomers and are also used in a variety of solvent applications.

The single largest end-use of mixed xylene is in the production of the p-xylene isomer, which consumed an estimated 4,107 million lb in 1978. o-Xylene isomer production consumed 1,046 million lb, m-xylene isomer production 88 million lb, and ethylbenzene, a natural constituent of mixed xylenes, 220 million lb. Separation of the various xylene isomers from mixed xylene is accomplished through distillation and crystallization.

Table 29-1. Mixed Xylene Production Source Summary*

Source	Isolated Mixed Xylene Product ($\bar{M}$ lb/yr)	Nonisolated Mixed Xylene Production ($\bar{M}$ lb/yr)	Total Mixed Xylene Production ($\bar{M}$ lb/yr)
Catalytic reformate	7,991	68,925	76,916
Pyrolysis gasoline	429	397	826
Toluene disproportionation	106	92	198
Coal-derived	29	4	33
Total	8,555	69,418	77,973

*See refs. 1 and 2.

Table 29-2. Nonisolated Mixed Xylene (as BTX) Production from Catalytic Reformate[a]

Region	Number of Sites	Reformate Capacity (M bbl/day)	Nonisolated Mixed Xylenes Produced (M̄ lb/yr)[b]	Average Nonisolated Mixed Xylenes Produced Per Site (M̄ lb/yr)
New England	0	0	0	0
Middle Atlantic	17	369,952	6,743	397
East North Central	28	624,178	11,377	406
West North Central	16	165,250	3,012	188
South Atlantic	5	57,660	1,051	210
East South Central	8	144,700	2,637	330
West South Central	71	1,649,303	30,061	423
Mountain	23	123,094	2,243	98
Pacific	33	647,461	11,801	358
Total	201	3,781,598	68,925	343

[a] See ref. 3.

[b] Total production is distributed based on capacity.

Table 29-3. Isolated Mixed Xylene Production from Catalytic Reformate[a]

Company	Location	Mixed Xylene Capacity (metric ton/yr)	Isolated Mixed Xylene Produced (M lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Amerada Hess	St. Croix, VI	457	699	Not in project scope
American Petrofina	Big Spring, TX	209	306	32 17 10/101 25 17
	Beaumont, TX	49	72	29 57 30/93 53 20
Ashland Oil	Catlettsburg, KY	98	143	38 22 39/82 35 58
	N. Tonawanda, NY	46	67	42 59 45/78 55 27
ARCO	Houston, TX	258	378	29 42 17/95 16 01
Charter Oil	Houston, TX	36	53	29 42 50/95 15 12
Cities Service	Lake Charles, LA	163	239	30 10 58/93 19 01
Coastal States	Corpus Christi, TX	55	80	27 48 43/97 26 28
Commonwealth	Penuelas, PR	343	502	Not in project scope
Crown	Pasadena, TX	46	67	29 44 40/95 10 30
Exxon	Baytown, TX	408	597	29 44 50/95 01 04
Gulf	Alliance, LA	196	287	29 50 00/90 00 10
Kerr McGee	Corpus Christi, TX	140	205	27 48 16/97 25 24
Marathon	Texas City, TX	36	53	29 22 22/94 54 58
Monsanto[c]	Texas City, TX	32	47	29 22 45/94 33 30
Phillips	Guayama, PR	326	477	Not in project scope
Quitana-Howell	Corpus Christi, TX	42	61	27 48 35/97 27 30
Shell	Deer Park, TX	245	359	29 42 55/95 07 33

Table 29-3 (concluded)

Company	Location	Mixed Xylene Capacity (metric ton/yr)	Isolated Mixed Xylene Produced (M lb/yr)[b]	Geographic Coordinates Latitude/Longitude
Chevron	Pascagoula, MS	212	310	30 19 04/88 28 37
	Richmond, CA	196	287	37 56 12/122 20 48
Amoco	Texas City, TX	800	1,171	29 21 40/94 55 50
	Whiting, IN	588	860	41 41 07/87 29 02
Sun	Corpus Christi, TX	78	114	27 49 53/97 31 30
	Marcus Hook, PA	65	95	39 48 45/75 24 51
	Toledo, OH	163	239	41 36 52/83 31 40
Tenneco	Chalmette, LA	130	190	30 03 30/89 58 30
Union Oil	Chicago, IL	33	48	41 38 33/88 03 02
Union Pacific	Corpus Christi, TX	10	15	27 48 10/97 35 29
Total		5,460	7,991	

[a] See refs. 1 and 2.

[b] Total isolated mixed xylene production distributed per mixed xylene extraction capacity.

[c] Monsanto (ref. 19) claims the above process no longer exist at this plant.

Table 29-4. Other Mixed Xylene Producers[a]

Company	Location	Production Capacity ($\bar{M}$ lb/yr)	Nonisolated Mixed Xylene Produced ($\bar{M}$ lb/yr)	Isolated Mixed Xylene Produced ($\bar{M}$ lb/yr)	Total Mixed Xylene Produced ($\bar{M}$ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
			Pyrolysis Gasoline			
ARCO	Channelview, TX	1179	79	168	247	29 50 04/95 06 43
Commonwealth	Penuelas, PR	454	30	91	121	Not in project scope
Dow	Freeport, TX	1134	76		76	28 59 12/95 01 00
Exxon	Baton Rouge, LA	816	55		55	30 09 10/90 54 20
Gulf	Cedar Bayou, TX	544	37		37	29 49 29/94 55 10
Mobile	Beaumont, TX	408	27		27	30 04 00/94 03 30
Monsanto[c]	Texas City, TX	340	23	61	84	29 15 00/95 12 40
Shell	Deer Park, TX	624	42		42	29 42 55/95 07 33
Union Carbide	Taft, LA	417	28	109	137	29 58 00/90 27 00
Total		5916	397	429	826	
			Coal-Derived			
Ashland	Catlettsburg, KY	13	1.6	11.4	13	38 22 39/82 35 58
	N. Tonawanda, NY	7	0.8	6.2	7	42 59 45/78 55 27
U.S. Steel	Clairton, PA	13	1.6	11.4	13	40 18 15/79 52 43
Total		33	4.0	29.0	33	

Table 29-4 (concluded)

Company	Location	Production Capacity ($\bar{M}$ lb/yr)	Nonisolated Mixed Xylene Produced ($\bar{M}$ lb/yr)	Isolated Mixed Xylene Produced ($\bar{M}$ lb/yr)	Total Mixed Xylene Produced ($\bar{M}$ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
		Toluene Disproportionation				
ARCO	Houston, TX	196	45	52	97	29 42 17/95 16 01
Sun	Marcus Hook, PA	202	47	54	101	39 48 45/75 24 51
Total		398	92	106	198	

[a] See refs. 1 and 2.

[b] Total production distributed based on production capacity.

[c] Monsanto (ref. 19) claims the above process no longer exist at this plant.

Table 29-5. End-Use Distribution—1978[a]
Mixed Xylene and Xylene Isomers

	Usage (M lb/yr)	Usage (%)
Mixed xylene as BTX (not isolated)	69,418	
Gasoline	69,418	100.0
Isolated mixed xylene	8,555	
p-Xylene isomer	4,107	48.0
o-Xylene isomer	1,046	12.2
m-Xylene isomer	88	1.0
Ethyl benzene	220	2.6
Gasoline backblending	2,158	25.2
Paint and coating solvent	496	5.8
Adhesives solvent	77	0.9
Chemical manufacturing solvent	77	0.9
Agricultural solvent	66	0.8
Other miscellaneous solvents	55	0.7
Net export	165	1.9
o-Xylene	1,046	
Phthalic anhydride	670	64.1
Gasoline backblending	21	2.0
Exports	355	33.9
p-Xylene	4,107	
Terephthalic acid	1,430	34.8
Dimethyl terephthalate	2,040	49.7
Net exports	620	15.1
Gasoline backblending	17	0.4
m-Xylene	88	
Isophthalic acid	98[b]	100.0

[a] See refs. 1, 2, and 4.

[b] Difference between production and use supplied by imports.

Individual locations producing xylene isomer are shown in Table 29-6.[4] Total isomer production was distributed based on the individual site's capacity. In this report ethyl benzene production has been grouped with the individual xylene isomers because it is a component of mixed xylenes.

The second largest use of isolated mixed xylenes is backblending into gasoline. This end-use consumed an estimated 2,158 million lb of isolated mixed xylenes representing 25.2% of 1978 isolated production.

The only other area of domestic use for mixed xylenes is in solvent applications which consumed an estimated 771 million lb in 1978. Use as a solvent in paints and coatings was the single largest solvent application. An estimated 496 million lb was consumed for this end-use. Other solvent applications include 77 million lb for adhesives and rubber solvent, 77 million lb for chemical and manufacturing solvent, 66 million lb for agricultural solvent (solvent carrier for pesticides), and 55 million lb for household proprietary product and printing ink solvent. Net exports consumed 165 million lb, representing 1.9% of production.

Each of the individual isomers has one primary outlet for end-use. o-Xylene is used almost exclusively as a chemical intermediate to produce phthalic anhydride which is used chiefly in phthalate plasticizers. An estimated 670 million lb of o-xylene was consumed for this use. Exports of o-xylene totaled 355 million lb, and the remaining 21 million lb was backblended into gasoline.

p-Xylene is used primarily to produce terephthalic acid and dimethyl terephthalate which are used as intermediates in the manufacture of polyester fiber. Consumption of p-xylene was estimated to have been 1430 million lb for terephthalate acid production and 2040 million lb for dimethyl terephthalate manufacture. Net exports consumed 620 million lb of p-xylene, and the remaining 17 million lb was backblended into gasoline.

m-Xylene is used exclusively to produce isophthalic acid, which is primarily used in the manufacture of polyester resins. A total of 98 million lb of m-xylene was consumed for this end-use, of which 10 million lb was imported. Xylene isomer end-user locations are summarized in Table 29-7.[4,5]

Table 29-6. Xylene Isomer Producers[a]

Company	Location	Isomer Capacity (M lb/yr)	Isomer Production (M lb/yr)[b]	Geographic Coordinates Latitude/Longitude
		o-Xylene Producers		
ARCO	Houston, TX	210	183	29 42 17/95 16 01
Corco	Ponce, PR	175	153	Not in project scope
Exxon	Baytown, TX	200	174	29 44 50/95 01 00
Monsanto[d]	Chocolate Bayou, TX	30	26	29 14 55/95 12 45
Phillips	Guayama, PR	130	113	Not in project scope
Shell	Deer Park, TX	165	144	29 42 55/95 07 34
Sun	Corpus Christi, TX	160	140	27 49 53/97 31 30
Tenneco	Chalmette, LA	130	113	30 03 30/89 58 30
Total		1200	1046	
		m-Xylene Producer		
Amoco	Texas City, TX	175	88	29 21 40/94 55 50
		p-Xylene Producers		
Amoco	Decatur, AL	1300	952	34 36 12/86 58 42
	Texas City, TX	900	659	29 21 40/94 55 50
ARCO	Houston, TX	360	264	29 42 17/95 16 01
Chevron	Pascagoula, MS	330	242	30 19 04/88 28 37
St. Croix	St. Croix, VI	600	440	Not in project scope
Exxon	Baytown, TX	420	308	29 44 50/95 01 00
Hercor	Penuelas, PR	600	440	Not in project scope
Phillips	Guayama, PR	470	344	Not in project scope
Shell	Deer Park, TX	110	80	29 42 55/95 07 34
Sun	Corpus Christi, TX	390	286	27 49 53/97 31 30
Tenneco	Chalmette, LA	125	92	30 03 30/89 58 30
Total		5605	4107	

Table 29-6 (concluded)

Company	Location	Isomer Capacity ($\bar{M}$ lb/yr)	Isomer Production ($\bar{M}$ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
		Ethylbenzene Producers[c]		
ARCO	Houston, TX	136	99	29 42 17/95 16 01
Charter	Houston, TX	35	25	29 42 50/95 15 12
Monsanto[d]	Chocolate Bayou, TX	59	43	29 14 55/95 12 45
Sun	Corpus Christi, TX	73	53	27 49 53/97 31 30
Total		303	220	

[a] See ref. 4.

[b] Total production distributed based on capacity.

[c] Ethylbenzene is considered to be a mixed xylene isomer.

[d] Monsanto (ref. 19) claims the above process has been sold.

Table 29-7. Xylene Isomer End-Users[a]

Company	Location	Production Capacity ($\bar{M}$ lb/yr)	o-Xylene Used ($\bar{M}$ lb/yr)[b]	Geographic Coordinates Latitude/Longitude
		Phthalic Anhydride Producers (o-Xylene)		
Allied	El Segundo, CA	36	26	33 56 30/118 26 35
BASF Wyandotte	Kearny, NJ	150	107	40 45 53/74 09 03
Exxon	Baton Rouge, LA	130	93	30 09 10/90 54 20
Koppers	Cicero, IL	235	168	41 48 44/87 45 04
Monsanto	Texas City, TX	150	107	29 22 45/94 33 30
Hooker	Arecibo, PR	87	62	Not in project scope
Chevron	Richmond, CA	50	36	37 56 12/122 20 48
Stepan	Millsdale, IL	100	71	41 26 03/88 09 48
Total		938	670	
		Isophthalic Acid Producer (m-Xylene)		
Amoco	Joliet, IL	240	98	41 26 48/88 10 41
		Dimethylterephthalic Acid Producers (p-Xylene)		
Du Pont	Old Hickory, TN	550	273	36 16 24/86 34 12
	Wilmington, NC	1250	622	34 10 00/77 56 06
Eastman Kodak	Columbia, SC	500	249	33 59 50/81 04 17
	Kingsport, TN	500	249	36 31 41/82 12 22
Hercofina	Wilmington, NC	1300	647	34 19 27/77 46 56
Total		4100	2040	
		Terephthalic Acid Producers (p-Xylene)		
Amoco	Cooper River, SC	1000	441	32 45 57/79 58 28
	Decatur, AL	2000	883	34 36 12/86 58 42
Hercofina	Wilmington, NC	240	106	34 19 27/77 46 56
Total		3240	1430	

[a] See refs. 4 and 5.

[b] Total use distributed based on production.

C. INCIDENTAL SOURCES

For the purpose of this report, the use of mixed xylenes in gasoline and the emissions resulting from gasoline evaporation and exhaust are considered to be incidental. Gasoline consumption in 1978 is estimated to have been 104,568 million gal.

II. EMISSIONS

A. PRODUCTION

Emission factors used to develop production and end-use emission estimates for mixed xylenes are shown in Table 29-8.[6—12] Process emissions originate from the reactor, distillation, and crystallization vents. Storage emissions represent the loss from both working and final product storage as well as loading and handling losses. Fugitive emissions are those which result from plant equipment leaks.

Xylene isomer emissions can occur from both mixed xylenes and individual isomer producers and end-users.

Total emissions of mixed xylenes and xylene isomers from the production of nonisolated mixed xylene via catalytic reformate are tabulated by geographic region in Table 29-9. Average emissions of each of the xylene isomers per each catalytic reformate producing site in the nine geographic regions are tabulated in Table 10. Total emissions of mixed xylenes from isolated mixed xylenes production are tabulated in Table 29-11. Emissions of individual isomers from this source are tabulated in Table 29-12. Total emissions of mixed xylenes from this catalytic reformate production were estimated to have been 9,858,760 lb. Individual isomer emissions were estimated by assuming that the weight composition of the individual isomers in the mixed xylene were 16.7% p-xylene, 20.5% o-xylene, 35.7% m-xylene, 2.9% toluene, 23.7% ethyl benzene, and 0.5% others.[13] Individual emission estimates from catalytic reformating production of p-xylene, o-xylene, and m-xylene are 1,540,455 lb, 1,890,978 lb, and 3,293,068 lb respectively.

Emissions of mixed xylenes from the other mixed xylene production sources are tabulated in Table 29-13. The mixed xylene emissions from pyrolysis gasoline,

Table 29-8. Xylene Emission Factors

	lb Xylene Lost per lb Produced (Used)				
Source	Process	Storage	Fugitive	Total	Derivation[a]
Mixed xylene - catalytic reformate	0.00003	0.00006	0.00003	0.00012	B[b]
Mixed xylene - pyrolysis gasoline	0.00007	0.00030	0.00003	0.00040	A[c]
Mixed xylene - toluene	0.00005	0.00010	0.00005	0.00020	D
Mixed xylene - coal-derived	0.00050	0.00060	0.00015	0.00125	D
o-Xylene - production	0.00209	0.00008	0.00038	0.00255	B[d]
m-Xylene - production	0.00158	0.00012	0.00030	0.00200	D
p-Xylene - production	0.00114	0.00019	0.00024	0.00157	B[e]
Ethylbenzene - production	0.00010	0.00005	0.00005	0.00020	D
Phthalic anhydride - production	0.00014	0.00002	0.00004	0.00020	C[f]
Isophthalic acid - production	0.00085	0.00005	0.00010	0.00100	C[f]
Dimethylterephthalate - production	0.00013	0.00003	0.00007	0.00023	A[g]
Terephthalic acid - production	0.00254	0.00011	0.00007	0.00272	A[g]

[a] A - Site visit data
B - State files
C - Published data
D - Hydroscience estimate

[b] See refs. 6—9.

[c] See ref. 10.

[d] See refs. 7 and 8.

[e] See ref. 7.

[f] See ref. 11.

[g] See ref. 12.

Table 29-9. Total Mixed Xylenes and Xylene Isomer Emissions from Catalytic Reformate (Nonisolated) Production*

Region	Number of Sites	Mixed Xylene Emissions (lb/yr)	Total Emissions (lb/yr)		
			p-Xylene	o-Xylene	m-Xylene
New England	0	0	0	0	0
Middle Atlantic	17	809,160	135,130	165,878	288,870
East North Central	28	1,365,240	227,995	279,874	487,391
West North Central	16	361,440	60,360	74,095	129,034
South Atlantic	5	126,120	21,062	25,855	45,025
East South Central	8	316,440	52,845	64,870	112,969
West South Central	71	3,607,320	602,422	739,501	1,287,813
Mountain	23	269,160	44,950	55,178	96,090
Pacific	33	1,416,120	236,492	290,305	505,555
Total	201	8,271,000	1,381,257	1,695,555	2,952,747

*See ref. 3.

Table 29-10. Average Xylene Isomer Emissions per Site from Catalytic Reformate (Nonisolated Mixed Xylene Production)

Region	Number of Sites	Average Emissions per Site					
		p-Xylene		o-Xylene		m-Xylene	
		(lb/yr)	(g/sec)*	(lb/yr)	(g/sec)*	(lb/yr)	(g/sec)*
New England	0	0	0	0	0	0	0.24
Middle Atlantic	17	7949	0.11	9,758	0.14	16,992	0.25
East North Central	28	8143	0.12	9,996	0.14	17,407	0.12
West North Central	16	3773	0.05	4,631	0.07	8,065	0.13
South Atlantic	5	4212	0.06	5,171	0.07	9,005	0.20
East South Central	8	6606	0.10	8,109	0.11	14,121	0.26
West South Central	71	8485	0.12	10,416	0.15	18,138	0.06
Mountain	23	1954	0.03	2,399	0.03	4,178	0.22
Pacific	33	7166	0.10	8,797	0.13	15,320	
Total	201						
Weighted average		6872		8,436		14,690	

*Based on 8760 hr/yr operation.

Table 29-11. Mixed Xylene Emissions from Catalytic Reformate (Isolated Mixed Xylenes) Production

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
Amerada Hess	St. Croix, VI	20,070	40,140	20,070	80,280	1.16
American Petrofina	Big Spring, TX	9,180	18,360	9,180	36,720	0.53
	Beaumont, TX	2,160	4,320	2,160	8,640	0.12
Ashland Oil	Catlettsburg, KY	4,290	8,580	4,290	17,160	0.25
	N. Tonawanda, NY	2,010	4,020	2,010	8,040	0.12
Arco	Houston, TX	11,340	22,680	11,340	45,360	0.65
Charter Oil	Houston, TX	1,590	3,180	1,590	6,360	0.09
Cities Service	Lake Charles, LA	7,170	14,340	7,170	28,680	0.41
Coastal States	Corpus Christi, TX	2,400	4,800	2,400	9,600	0.14
Commonwealth	Penuelas, PR	15,060	30,120	15,060	60,240	0.87
Crown	Pasadena, TX	2,010	4,020	2,010	8,040	0.12
Exxon	Baytown, TX	17,910	35,820	17,910	71,164	1.02
Gulf	Alliance, LA	8,610	17,220	8,610	34,440	0.50
Kerr-McGee	Corpus Christi, TX	6,150	12,300	6,150	24,600	0.35
Marathon	Texas City, TX	1,590	3,180	1,590	6,360	0.09
Phillips	Guayama, PR	14,310	28,620	14,310	57,240	0.82
Quintana-Howell	Corpus Christi, TX	1,830	3,660	1,830	7,320	0.11
Shell	Deer Park, TX	10,770	21,540	10,770	43,080	0.62
Chevron	Pascagoula, MS	9,300	18,600	9,300	37,200	0.54
	Richmond, CA	8,610	17,220	8,610	34,440	0.50

Table 29-11 (concluded)

Company	Location	Emissions (lb/yr)			Total Emissions	
		Process	Storage	Fugitive	(lb/yr)	(g/sec)*
Amoco	Texas City, TX	193,750	387,500	193,750	775,000	2.02
	Whiting, IN	25,800	51,600	25,800	103,200	1.49
Sun	Corpus Christi, TX	3,420	6,840	3,420	13,680	0.20
	Marcus Hook, PA	2,850	5,700	2,850	11,400	0.16
	Toledo, OH	7,170	14,340	7,170	28,680	0.41
Tenneco	Chalmette, LA	5,700	11,400	5,700	22,800	0.33
Union Oil	Chicago, IL	1,440	2,880	1,440	5,760	0.08
Union Pacific	Corpus Christi, TX	450	900	450	1,800	0.03
Total		396,940	793,880	396,940	1,587,760	

*Based on 8760 hr/yr operation.

Table 29-12. Xylene Isomer Emissions from Isolated Mixed Xylene Catalytic Reformate Producers

Company	Location	p-Xylene Total Emissions (lb/yr)	p-Xylene Total Emissions (g/sec)*	o-Xylene Total Emissions (lb/yr)	o-Xylene Total Emissions (g/sec)*	m-Xylene Total Emissions (lb/yr)	m-Xylene Total Emissions (g/sec)*
Amerada Hess	St. Croix, VI	13,407	0.19	16,457	0.24	28,660	0.41
American Petrofina	Big Springs, TX	6,132	0.09	7,528	0.11	13,109	0.19
	Beaumont, TX	1,443	0.02	1,771	0.03	3,084	0.04
Ashland Oil	Catlettsburg, KY	2,866	0.04	3,518	0.05	6,126	0.09
	N. Tonawanda, NY	1,343	0.02	1,648	0.02	2,870	0.04
Arco	Houston, TX	7,575	0.11	9,299	0.13	16,194	0.23
Charter Oil	Houston, TX	1,062	0.02	1,304	0.02	2,271	0.03
Cities Service	Lake Charles, LA	4,790	0.07	5.879	0.08	10,239	0.15
Coastal States	Corpus Christi, TX	1,603	0.02	1,968	0.03	3,427	0.05
Commonwealth	Penuelas, PR	10,060	0.14	12,349	0.18	21,506	0.31
Crown	Pasadena, TX	1,343	0.02	1,648	0.02	2,870	0.04
Exxon	Baytown, TX	11,884	0.17	14,589	0.21	25,406	0.37
Gulf	Alliance, LA	5,751	0.08	7,060	0.10	12,295	0.18
Kerr-McGee	Corpus Christi, TX	4,108	0.06	5,043	0.07	8,782	0.13
Marathon	Texas City, TX	1,062	0.02	1,304	0.02	2,271	0.03
Phillips	Guayama, PR	9,559	0.14	11,734	0.17	20,435	0.29
Quintana-Howell	Corpus Christi, TX	1,222	0.02	1,501	0.02	2,613	0.04
Shell	Deer Park, TX	7,194	0.10	8,831	0.13	15,380	0.22
Chevron	Pascagoula, MS	6,212	0.09	7,626	0.11	13,280	0.19
	Richmond, CA	5,751	0.08	7,060	0.10	12,295	0.18

Table 29-12 (concluded)

Company	Location	p-Xylene Total Emissions (lb/yr)	p-Xylene Total Emissions (g/sec)*	o-Xylene Total Emissions (lb/yr)	o-Xylene Total Emissions (g/sec)*	m-Xylene Total Emissions (lb/yr)	m-Xylene Total Emissions (g/sec)*
Amoco	Texas City, TX	23,467	0.34	28,807	0.41	50,166	0.72
	Whiting, IN	17,234	0.25	21,156	0.30	36,842	0.53
Sun	Corpus Christi, TX	2,285	0.03	2,804	0.04	4,884	0.07
	Marcus Hook, PA	1,904	0.03	2,337	0.03	4,070	0.06
	Toledo, OH	4,790	0.07	5,879	0.08	10,239	0.15
Tenneco	Chalmette, LA	3,808	0.05	4,674	0.07	8,140	0.12
Union Oil	Chicago, IL	962	0.01	1,181	0.02	2,056	0.03
Union Pacific	Corpus Christi, TX	301	Nil	369	0.01	643	0.01
Total		159,198		195,423		340,321	

*Based on 8760 hr/yr operation.

Table 29-13. Mixed Xylene Emissions from Other Mixed Xylene Producers

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		Pyrolysis-Gasoline				
ARCO	Channelview, TX	17,290	74,100	7,410	98,800	1.42
Commonwealth	Penuelas, PR	8,470	36,300	3,630	48,400	0.70
Dow	Freeport, TX	5,320	22,800	2,280	30,400	0.44
Exxon	Baton Rouge, LA	3,850	16,500	1,650	22,000	0.32
Gulf	Cedar Bayou, TX	2,590	11,100	1,110	14,800	0.21
Mobile	Beaumont, TX	1,890	8,100	810	10,800	0.16
Shell	Deer Park, TX	2,940	12,600	1,260	16,800	0.24
Union Carbide	Taft, LA	9,590	41,100	4,110	54,800	0.79
Total		51,940	222,600	22,260	296,800	
		Coal-Derived				
Ashland	Catlettsburg, KY	6,500	7,800	1,950	16,250	0.23
	N. Tonawanda, NY	3,500	4,200	1,050	8,750	0.13
U.S. Steel	Clairton, PA	6,500	7,800	1,950	16,250	0.23
Total		16,500	19,800	4,950	41,250	
		Toluene Disproportionation				
ARCO	Houston, TX	4,850	9,700	4,850	19,400	0.28
Sun	Marcus Hook, PA	5,050	10,100	5,050	20,200	0.29
Total		9,900	19,800	9,900	39,600	

*Based on 8760 hr/yr operation.

toluene disproportionation and coal-derived production sources were 296,800 lb, 39,600 lb, and 41,250 lb respectively.

Emissions of the individual isomers from other mixed xylene producers are shown in Table 29-14, where the same compositions employed in catalytic reformate computations are used.

Individual isomer emissions from pyrolysis gasoline production were 49,566 lb p-xylene, 60,844 lb o-xylene, 105,958 lb m-xylene; from toluene disproportionation emissions were 6,613 lb p-xylene, 8,118 lb o-xylene, 14,137 lb m-xylene; and from coal-derived production emissions were 6,889 lb p-xylene, 8,456 lb o-xylene, and 14,726 lb m-xylene.

Other associated emissions would primarily include benzene and toluene from all four production sources.

B. USES

Individual isomer emissions from each of the individual isomer production sites are tabulated in Table 29-15.

o-Xylene emissions from its production were estimated to have been 2,601,000 p-Xylene production emissions totaled 4,870,299 lb, and m-xylene production emissions were 15,800 lb.

The emissions from the production of ethylbenzene from mixed xylene are shown in Table 29-16. Total mixed xylene emissions are estimated to have been 15,600 lb. Individual isomer emission totals based on the reported composition mentioned earlier in this report are 2,605 lb p-xylene, 3,198 lb o-xylene, and 5,569 lb m-xylene.

For the purpose of this report all mixed xylenes used in solvent applications for adhesives and rubber, agricultural pesticides, and household products were assumed to be released to the atmosphere. Specific end-user locations are considered too widespread (individual consumer-type uses) to identify regionally.

Table 29-14. Xylene Isomer Emissions from Other Mixed Xylene Producers

Company	Location	p-Xylene Total Emissions (lb/yr)	p-Xylene Total Emissions (g/sec)*	o-Xylene Total Emissions (lb/yr)	o-Xylene Total Emissions (g/sec)*	m-Xylene Total Emissions (lb/yr)	m-Xylene Total Emissions (g/sec)*
		Pyrolysis Gasoline					
ARCO	Channelview, TX	16,500	0.24	20,254	0.29	35,272	0.51
Commonwealth	Penuelas, PR	8,083	0.12	9,922	0.14	17,279	0.25
Dow	Freeport, TX	5,077	0.07	6,232	0.09	10,853	0.16
Exxon	Baton Rouge, LA	3,674	0.05	4,510	0.07	7,854	0.11
Gulf	Cedar Bayou, TX	2,472	0.04	3,034	0.04	5,284	0.07
Mobile	Beaumont, TX	1,804	0.03	2,214	0.03	3,856	0.06
Shell	Deer Park, TX	2,806	0.04	3,444	0.05	5,998	0.09
Union Carbide	Taft, LA	9,152	0.13	11,234	0.16	19,564	0.28
Total		49,566		60,844		105,958	
		Coal-Derived					
Ashland	Catlettsburg, KY	2,714	0.04	3,331	0.05	5,801	0.08
	N. Tonawanda, NY	1,461	0.02	1,794	0.03	3,124	0.05
U.S. Steel	Clairton, PA	2,714	0.04	3,331	0.05	5,801	0.08
Total		6,889		8,456		14,726	
		Toluene Disproportionation					
ARCO	Houston, TX	3,240	0.05	3,977	0.06	6,926	0.10
Sun	Marcus Hook, PA	3,373	0.05	4,141	0.06	7,211	0.10
Total		6,613		8,118		14,137	

*Based on 8760 hr/yr operation.

Table 29-15. Xylene Isomer Emissions from Xylene Isomer Producers

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		o-Xylene Producers				
ARCO	Houston, TX	382,470	14,640	69,540	466,650	6.72
Corco	Ponce, PR	319,770	12,240	58,140	390,150	5.62
Exxon	Baytown, TX	363,660	13,920	66,120	443,700	6.39
Phillips	Guayama, PR	237,170	9,040	42,940	288,150	4.15
Shell	Deer Park, TX	300,960	11,520	54,720	367,200	5.29
Sun	Corpus Christi, TX	292,600	11,200	53,200	357,000	5.14
Tenneco	Chalmette, LA	236,170	9,040	42,940	288,150	4.15
Total		2,131,800	81,600	387,600	2,601,000	
		m-Xylene Producer				
Amoco	Texas City, TX	12,482	948	2,370	15,800	0.23
		p-Xylene Producers				
Amoco	Decatur, AL	509,717	84,953	107,309	701,979	10.10
	Texas City TX	181,238	30,206	38,155	249,600	3.59
ARCO	Houston, TX	300,960	50,160	63,360	414,480	5.97
Chevron	Pascagoula, MS	275,880	45,980	58,080	379,940	5.47
St. Croix	St. Croix, VI	501,600	83,600	105,600	690,800	9.94
Exxon	Baytown, TX	351,120	58,520	73,920	483,560	6.96
Hercor	Penuelas, PR	501,600	83,600	105,600	690,800	9.94
Phillips	Guayama, PR	392,160	65,360	82,560	540,080	7.78
Shell	Deer Park, TX	91,200	15,200	19,200	125,600	1.81
Sun	Corpus Christi, TX	326,040	54,340	68,640	449,020	6.46
Tenneco	Chalmette, LA	104,880	17,480	22,080	144,440	2.08
Total		3,536,395	589,399	744,504	4,870,299	

*Based on 8760 hr/yr operation.

Table 29-16. **Mixed Xylene and Xylene Isomer Emissions from Ethylbenzene Production**

Company	Location	Mixed Xylene Emissions (lb/yr)				p-Xylene Total Emissions		o-Xylene Total Emissions		m-Xylene Total Emissions	
		Process	Storage	Fugitive	Total	(lb/yr)	(g/sec*)	(lb/yr)	(g/sec*)	(lb/yr)	(g/sec*)
Charter	Houston, TX	2,500	1,250	1,250	5,000	835	0.01	1,025	0.01	1,785	0.03
Sun	Corpus Christi, TX	5,300	2,650	2,650	10,000	1,770	0.03	2,173	0.03	3,784	0.05
		7,800	3,900	3,900	15,600	2,605		3,198		5,569	

*Based on 8760 hr/yr operation.

ARCO Houston, TX No longer has an ethylbenze production facility (ref. 18)

Hydroscience estimates that 15% of the mixed xylene used as solvent, in paints and coatings, and in chemical and manufacturing applications is consumed as fuel. The remaining mixed xylene is released to the atmosphere. Again, specific source/locations could not be identified nor could a further breakdown of use quantities be obtained for regional distribution. Emission estimates for the individual isomers from solvent applications are shown in Table 29-17. Emissions were 114,395,000 lb p-xylene, 140,425,000 lb o-xylene, and 244,545,000 lb m-xylene.

Emissions of the individual isomers from their chemical end-users are tabulated in Table 29-18. Phthalic anhydride manufacture contributed 132,600 lb of o-xylene, isophthalic acid production released 98,000 lb of m-xylene, and terephthalic acid and dimethyl terephthalate yielded emissions of p-xylene of 469,200 lb and 2,152,641 lb, respectively.

C. INCIDENTAL SOURCES

Since gasoline consumes 92% of all mixed xylenes produced, it is one of the largest sources of mixed xylenes emissions.

There are three distinct sources of mixed xylenes emissions from gasoline use. They include evaporation from its use in automobiles, evaporation from gasoline marketing activities such as bulk and service stations, and emissions from the exhaust of automobiles. Individual xylene isomer emissions are estimated to have been 2,138,500 lb p-xylene, 2,138,500 lb o-xylene, and 5,193,450 lb m-xylene. These estimates were made by using an emission factor of 0.004735 lb hydrocarbon lost per lb gasoline consumed,[14] assuming the weight composition of p-, o-, and m- isomers in the gasoline vapor were 0.07%, 0.07%, and 0.17%, respectively.[15] The total emissions of each isomer from gasoline marketing are distributed in Table 29-19 by the total number of service stations in each geographic region.

Xylene isomer emissions are estimated to have been 1,967,100 lb p-xylene, 1,967,100 o-xylene, and 4,777,400 lb m-xylene from automobile gasoline evaporation using an emission factor of 0.83 g/mile hydrocarbon evaporative loss.[16] Average mileage was assumed to be 14.7 mile/gal[14] and the xylene isomer composition in the vapor was assumed to be the same as reported above.

Table 29-17. Xylene Isomer Emissions from Mixed Xylene Solvent Uses*

	Total Mixed Xylene Emissions (M lb/yr)	p-Xylene Emissions (M lb/yr)	o-Xylene Emissions (M lb/yr)	m-Xylene Emissions (M lb/yr)
Paints and coatings	422	70.474	86.510	150.654
Adhesive, rubber	77	12.859	15.785	27.489
Chemical, automotive	65	10.855	13.325	23.205
Agricultural pesticides	66	11.022	13.530	23.562
Household products, printing inks	55	9.185	11.275	19.635
Total	685	114.395	140.425	244.545

*See ref. 2.

Table 29-18. Xylene Isomer Emissions from Users

Company	Location	Emissions (lb/yr) Process	Emissions (lb/yr) Storage	Emissions (lb/yr) Fugitive	Total Emissions (lb/yr)	Total Emissions (g/sec)*
		Phthalic Anhydride Producers (o-Xylene)				
Allied	El Segundo, CA	3,640	520	1,040	5,200	0.07
BASF Wyandotte	Kearny, NJ	14,980	2,140	4,280	21,400	0.31
Exxon	Baton Rouge, LA	13,020	1,860	3,720	18,600	0.27
Koppers	Cicero, IL	23,520	3,360	6,720	33,600	0.48
Monsanto	Texas City, TX	14,000	2,000	4,000	20,000	0.29
Hooker	Arecibo, PR	8,680	1,240	2,480	12,400	0.18
Chevron	Richmond, CA	5,040	720	1,440	7,200	0.10
Stepan	Millsdale, IL	9,940	1,420	2,840	14,200	0.20
Total		92,820	13,260	26,520	132,600	
		Isophthalic Acid Producer (m-Xylene)				
Amoco	Joliet, IL	83,300	4,900	9,800	98,000	1.41
		Dimethylterephthalate Producers (p-Xylene)				
Du Pont	Old Hickory, TN	35,490	8,190	19,110	62,790	0.90
	Wilmington, NC	87,360	18,660	43,540	143,060	2.06
Eastman Kodak	Columbia, SC	32,370	7,470	17,430	57,270	0.82
	Kingsport, TN	32,370	7,470	17,430	57,270	0.82
Hercofina	Wilmington, NC	84,110	19,410	45,290	148,810	2.14
Total		265,200	61,200	142,800	469,200	
		Terephthalic Acid Producers (p-Xylene)				
Amoco	Cooper River, SC	687,574	29,777	18,949	736,300	10.59
	Decatur, AL	1,053,373	45,618	29,030	1,128,021	16,22
Hercofina	Wilmington, NC	269,240	11,660	7,420	288,320	4.15
Total		2,010,187	87,055	55,399	2,152,641	

*Based on 8760 hr/yr operation.

Table 29-19. Xylene Isomer Emissions from Gasoline Marketing[a]

Region	Number of Sites	o-Xylene Emissions (lb/yr)	m-Xylene Emissions (lb/yr)	p-Xylene Emissions (lb/yr)
New England	11,105	104,831	254,638	104,831
Middle Atlantic	28,383	267,935	650,822	267,935
East North Central	42,270	399,029	969,251	399,029
West North Central	23,304	219,990	534,361	219,990
South Atlantic	37,286	351,980	854,968	351,980
East South Central	16,313	153,995	374,057	153,995
West South Central	28,336	267,492	649,744	267,492
Mountain	12,815	120,974	293,848	120,974
Pacific	26,647	251,548	611,016	251,548
Total	226,459	2,138,500[b]	5,193,400[c]	2,138,500[b]

[a] See ref. 14.

[b] Average 9.44 lb/yr per site (0.00014 g/sec).

[c] Average 22.93 lb/yr per site (0.00033 g/sec).

Xylene isomer emissions from automobile exhaust were estimated to have been 108,345,600 lb p-xylene, 119,180,000 lb o-xylene, and 195,022,100 lb m-xylene using an emission factor of 3.2 g/mile[16] of hydrocarbons in the exhaust. Average mileage was assumed to be 14.7 mile/gal[14] and xylene isomer weight composition of the hydrocarbons in the exhaust were 1.0% p-xylene, 1.1% o-xylene, and 1.3% m-xylene.[17]

Vent parameter data for both production and end-uses of mixed xylene and xylene isomers are summarized in Table 29-20.

The total nationwide emissions of p-xylene, o-xylene, and m-xylene are estimated to have been 235,944,470 lb, 268,415,790 lb, and 453,085,160 lb, respectively. Total emissions are summarized in Table 29-21 for all three isomers.

Table 29-20. Xylene Vent Parameter Data*

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft x ft)
Production - Catalytic Reformate						
Process	11	54	3.0	300	12	
Storage	10	30	0.33	80		
Fugitive						800 x 1400
Production - Pyrolysis Gasoline						
Process	4	250	2.50	100	210	
Storage	9	30	0.17	80		
Fugitive						600 x 1200
Production - Coal Derived						
Process	2	60	1.5	120	40	
Storage	3	24	0.25	80		
Fugitive						400 x 400
Production - Toluene Disproportionation						
Process	3	60	1.5	150	60	
Storage	4	30	0.25	80		
Fugitive						300 x 600
o-Xylene Production						
Process	3	100	2.5	300	13	
Storage	8	30	0.25	80		
Fugitive						300 x 300

Table 29-20 (Continued)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area (ft x ft)
p-Xylene Production						
Process	5	125	3.5	700	3	
Storage	8	30	0.25	75		
Fugitive						300 x 300
m-Xylene Production						
Process	2	60	1.0	150	10	
Storage	6	24	0.17	80		
Fugitive						300 x 300
Ethyl Benzene Production						
Process	2	100	1.0	115	5	
Storage	4	30	0.17	80		
Fugitive						200 x 500
Phthalic Anhydride						
Process	2	60	0.5	150	10	
Storage	4	24	0.17	80		
Fugitive						200 x 200
Isophthalic Acid						
Process	2	60	1.0	180	20	
Storage	4	24	0.25	80		
Fugitive						200 x 200

Table 29-20 (concluded)

Source	Number of Stacks	Vent Height (ft)	Vent Diameter (ft)	Discharge Temperature (°F)	Velocity (ft/sec)	Discharge Area ft x ft
Terephthalic Acid						
Process	6	100	1.5	120	15	
Storage	4	30	0.33	80		
Fugitive						300 x 500
Dimethylterephthalate						
Process	3	100	2.0	175	25	
Storage	4	24	0.25	80		
Fugitive						300 x 600

*Building cross-section

Phthalic Anhydride - 100 m^2

Isophthalic Acid - 40 m^2

All Others - 200 m^2

Table 29-21. 1978 Nationwide Emissions of Xylene Isomers

	Nationwide Emissions (lb/yr)
p-Xylene	
Mixed xylene production	1,603,523
Mixed xylene solvent use	114,395,000
Ethyl benzene production	2,605
p-Xylene production	4,870,299
Terephthalic acid production	2,152,641
Dimethylterephthalate production	469,200
Gasoline marketing - evaporation	2,138,500
Gasoline automobile - evaporation	1,967,100
Gasoline automobile - exhaust	108,345,600
Total	235,944,470
o-Xylene	
Mixed xylene production	1,968,396
Mixed xylene solvent use	140,425,000
Ethyl benzene production	3,198
o-Xylene production	2,601,000
Phthalic anhydride	132,600
Gasoline marketing - evaporation	2,138,500
Gasoline automobile - evaporation	1,967,100
Gasoline automobile - exhaust	119,180,000
Total	268,415,790
m-Xylene	
Mixed xylene production	3,427,889
Mixed xylene solvent use	244,545,000
Ethyl benzene production	5,569
m-Xylene production	15,800
Isophthalic acid	98,000
Gasoline marketing - evaporation	5,193,400
Gasoline automobile - evaporation	4,777,400
Gasoline automobile - exhaust	195,022,100
Total	453,085,160

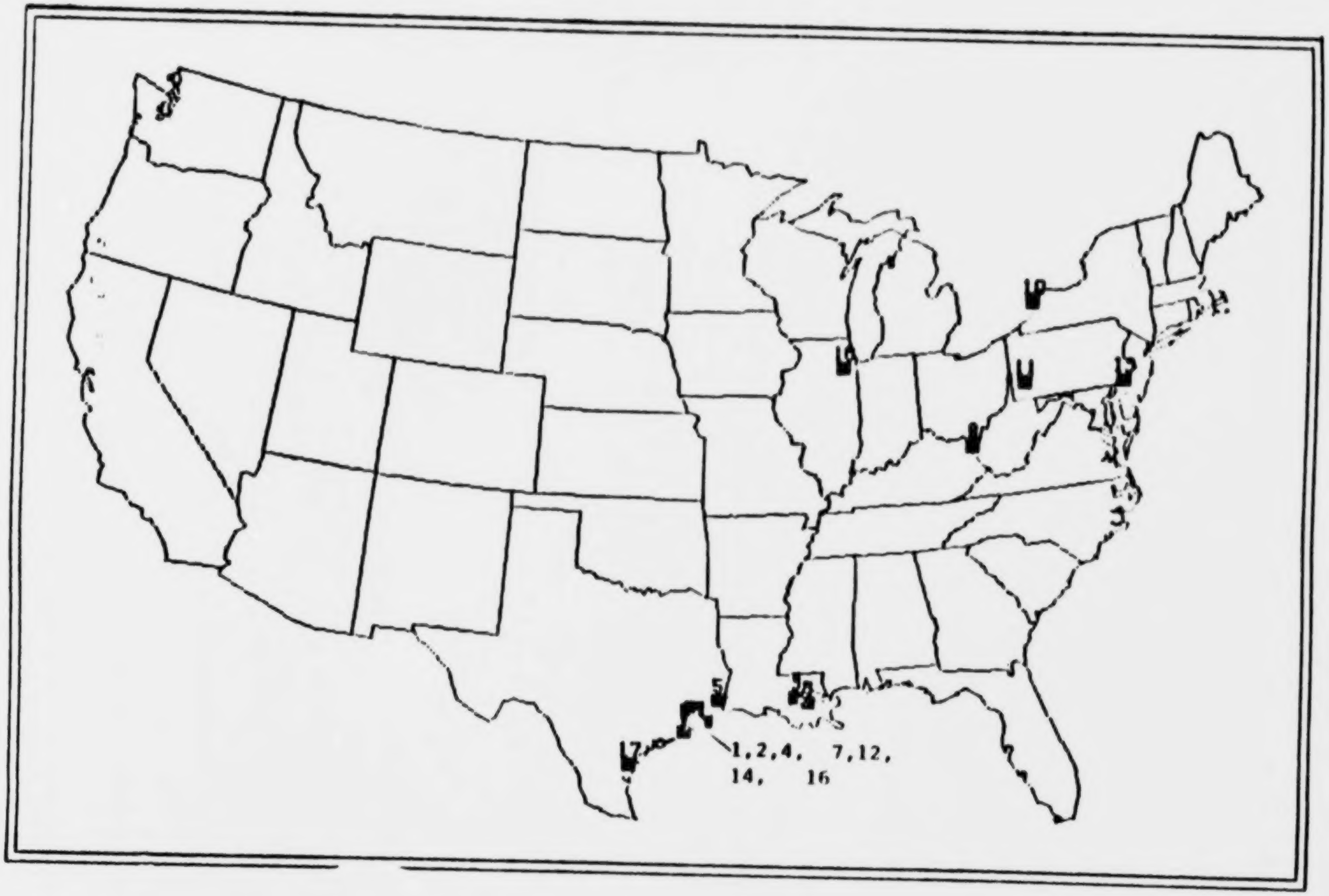

5
17
1,2,4,
7,12,
14,
16
3,

FIGURE 29-1. SPECIFIC POINT SOURCES OF m-XYLENE EMISSIONS

Table 29-22. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF m-XYLENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ARCO	CHANNELVIEW, TX	29 50 04	095 06 43	12906	1	1	.088848	.380866	.038087
2	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	.027360	.117215	.011722
3	EXXON	BATON ROUGE, LA	30 09 10	090 54 20	13970	1	1	.021240	.084814	.008482
4	GULF	CEDAR BAYOU, TX	29 49 29	094 55 10	12923	1	1	.013320	.057024	.005702
5	MOBILE	BEAUMONT, TX	30 04 14	094 03 40	12917	1	1	.009720	.041616	.004162
7	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	1	1	.015120	.064799	.006480
8	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	1	1	.049318	.211247	.021125
9	ASHLAND	CATLETTSBURG, KY	38 22 39	082 35 58	13866	2	2	.033406	.040103	.010080
10	ASHLAND	N. TOWAWANDA, NY	42 59 45	078 55 27	14747	2	2	.018000	.021600	.005400
11	U.S. STEEL	CLAIRTON, PA	40 18 15	079 52 43	14762	2	2	.033406	.040103	.010080
12	SUN	MARCUS HOOK, PA	39 48 45	075 24 51	13739	4	3	.025920	.051839	.025920
13	AMOCO	TEXAS CITY, TX	29 21 40	094 55 50	12906	5	4	.179533	.013635	.034089
14	CHARTER	HOUSTON, TX	29 42 50	095 15 12	12906	6	5	.012816	.006422	.006422
16	SUN	CORPUS CRISTI, TX	27 50 00	097 31 25	12925	6	5	.027216	.013680	.013680
17	AMOCO	JOLIET, IL	41 26 48	088 10 41	14855	7	6	1.199518	.070561	.141121

705<

TABLE 29-22. (Concluded)

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* Plant types:

Type 1: Plant produces mixed xylene (gasoline pyrolysis)
Type 2: Plant produces mixed xylene (coal-derived)
Type 3: Plant produces mixed xylene (toluene disproportionation), and O-ethylbenzene
Type 4: Plant produced mixed xylene (toluene disproportionation)
Type 5: Plant produces isolated m-xylene
Type 6: Plant produces ethylbenzene
Type 7: Plant produces isophthalic acid.

† Source types:

Type 1: Mixed xylene production (gasoline pyrolysis)
Type 2: Mixed xylene production (coal derived)
Type 3: Mixed xylene production (toluene disproportionation)
Type 4: m-Xylene isolation
Type 5: Ethylbenzene isolation
Type 6: Isophthalic acid production

TABLE 29-23. EXPOSURE AND DOSAGE OF m-XYLENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level ($\mu g/m^3$)	Population Exposed (persons)	Dosage [($\mu g/m^3$) . persons]
25	0	-
10	0	-
5	2	14.4
2.5	8	35.3
1	87	145
0.5	422	371
0.25	1,230	672
0.1	6,788	1,480
.05	56,643	4,690
.025	239,788	11,200
.01	447,807	14,500
.005	908,322	17,500
.0025	1,533,264	19,800
3.74×10^{-5}	6,630,088	24,100

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*The lowest annual average concentration occuring within 20 km of the specific point source.

TABLE 29-24. EMISSIONS RATES AND NUMBER OF GENERIC POINT SOURCES OF m-XYLENE

Region	Mixed Xylene Production (Catalytic Reforming)		Gasoling Marketing	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0	0	0.00033	11,105
Middle Atlantic	0.251	17	0.00033	28,383
East North Central	0.276	28	0.00033	42,270
West North Central	0.116	16	0.00033	23,304
South Atlantic	0.130	5	0.00033	37,286
East South Central	0.233	8	0.00033	16,313
West South Central	0.313	71	0.00033	28,336
Mountain	0.0602	23	0.00033	12,815
Pacific	0.226	33	0.00033	26,647

TABLE 29-25. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF m-XYLENE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)			Dosage [$10^6(\mu g/m^3) \cdot$ persons]		
	Mixed Xylene Production	Gasoline Marketing	U.S Total	Mixed Xylene Production	Gasoline Marketing	U.S. Total
5	0.5	0	0.5	2.7	0	2.7
2.5	9.5	0	9.5	30.5	0	30.5
1	87	0	87	144	0	144
0.5	311	0	311	300	0	300
0.25	1,450	0	1,450	540	0	540
0.1	3,350	0	3,350	877	0	877
0.05	7,830	0	7,830	1,200	0	1,200
0.025	--	--	--	1,470	58	1,530
0.01	--	--	--	1,910	334	2,250
0.005	--	--	--	2,310	673	2,980
0.0025	--	--	--	2,650	983	3,640
0.001	--	--	--	2,840	1,490	4,320
0.0005	--	--	--	2,860	2,010	4,870
0.00025	--	--	--	2,860	2,670	5,530
0	--	--	--	2,860	7,690	10,600

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 29-26. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF m-XYLENE

Parameter	Value
Daytime decay rate (K_d)	1.12×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	3187 gm/sec
Paint/coatings solvent emissions	2169 gm/sec
Adhesive emissions	396 gm/sec
Agricultural pesticide emissions	339 gm/sec
Miscellaneous	283 gm/sec
Nationwide mobile source emissions (E_M)	3211 gm/sec
Chemical (automobile) emissions	334 gm/sec
Motor vehicle gasoline evaporation	69 gm/sec
Motor vehicle exhaust emissions	2808 gm/sec
Ratio of truck emissions to auto emissions (R_M)	3

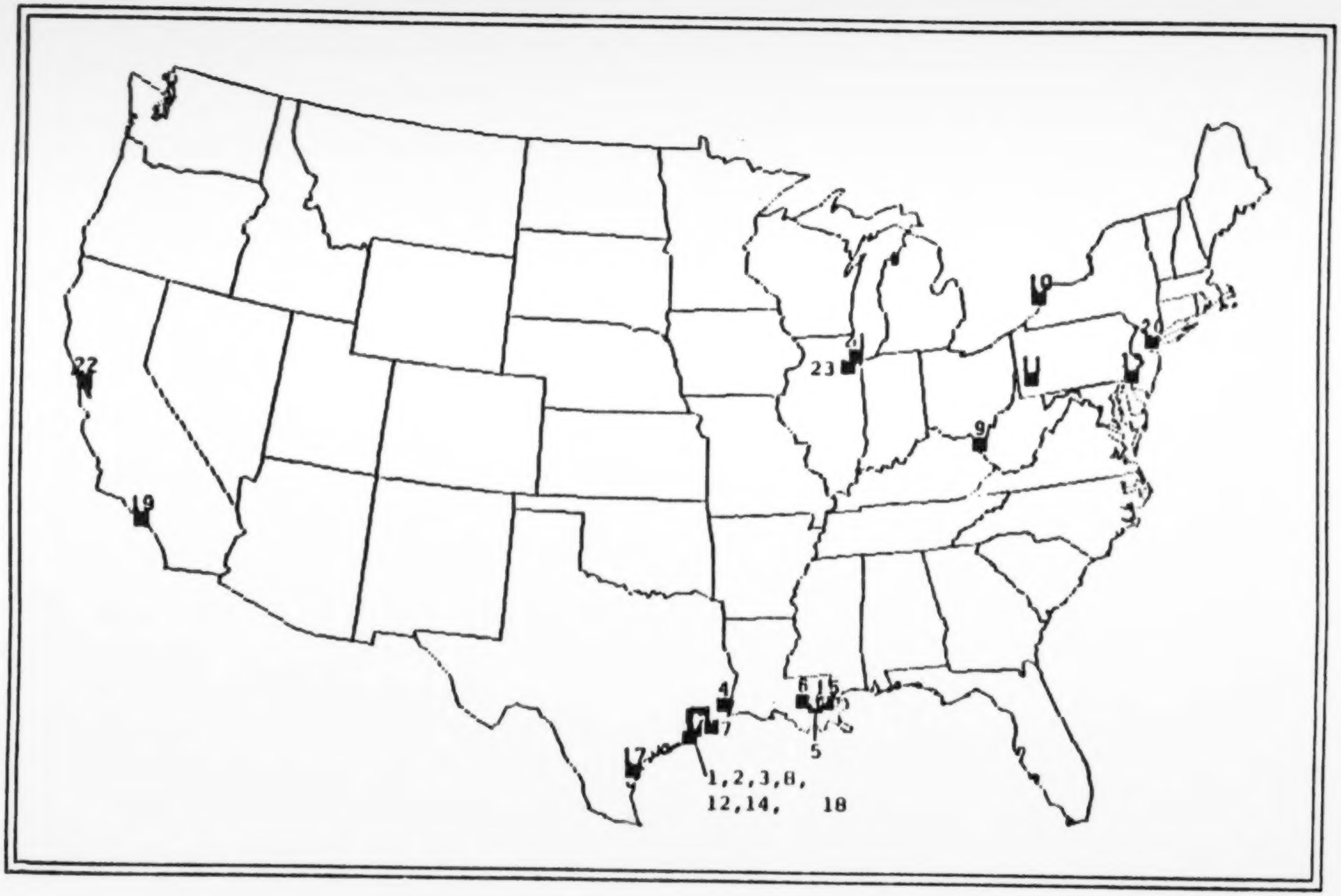
TABLE 29-27. m-XYLENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
25.000000	58188	1501677.1	0.	54.0	46.0	100.0	0.	0.
10.000000	505140	11454086.4	0.	73.5	26.5	100.0	0.	0.
5.000000	12846113	95797171.5	0.	71.8	28.2	100.0	0.	0.
2.500000	39492498	191324441.7	0.	63.6	36.4	98.8	.4	.9
1.000000	121659730	315706727.3	0.	60.1	39.9	93.8	3.1	3.1
0.	158679135	341146520.1	0.	59.4	40.6	90.8	3.5	5.7

TABLE 29-28. EXPOSURE AND DOSAGE SUMMARY OF m-XYLENE

Concentration Level (ug/m^3)	Populate Exposure (persons)				Dosage [(ug/m^3) . persons]			
	Specific Point Source	General Point Source	Area Source	U. S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
25	0	0	58,188	58,200	-	0	1,501,077	1,501,077
10	0	0	505,140	505,140	-	0	11,454,086	11,455,566
5	2	0	12,846,113	--	14.4	91,100	95,797,171	96,000,000
2.5	8	500	39,492,498	--	35.3	176,000	191,324,441	191,500,000
1	87	9,500	121,659,730	--	145	338,000	315,706,727	316,000,000
0.5	422	87,000	--	--	371	491,000	--	--
0.25	1,230	311,000	--	--	672	607,000	--	--
0.1	6,788	1,450,000	--	--	1,480	905,000	--	--
0	6,630,088	3,350,000	158,679,135	--	24,100	7,650,000	341,146,000	348,800,000

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.


10
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22
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1,2,3,8,
12,14,
18
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5

FIGURE 29-2. SPECIFIC POINT SOURCES OF o-XYLENE EMISSIONS

TABLE 29-29. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF o-XYLENE

No.	Company	Site	Latitude	Longitude	Star Station	Plant* Type	Source+ Type	Emissions (GM/SEC) Process	Storage	Fugitive
1	ARCO	CHANNELVIEW, TX	29 50 04	095 06 43	12906	1	1	.050973	.021888	.002189
2	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	.015696	.067320	.006739
3	GULF	CEDAR BAYOU, TX	29 49 29	094 55 10	12923	1	1	.007632	.032759	.003283
4	MOBILE	BEAUMONT, TX	30 04 14	094 03 40	12917	1	1	.005616	.023904	.002399
5	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	13970	1	1	.028368	.121391	.012139
6	EXXON	BATON ROUGE, LA	30 09 10	090 54 20	13970	2	1	.015696	.067320	.006739
							6	.187487	.026784	.053567
								.201367	.028767	.057533
8	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	3	1	.008640	.037152	.003715
							4	4.333777	.165887	.787957
9	ASHLAND	CATLETTSBURG, KY	38 22 39	082 35 58	13866	4	2	.019152	.023040	.005760
10	ASHLAND	N. TONAWANDA, NY	42 59 45	078 55 27	14747	4	2	.010368	.012384	.003096
11	U. S. STEEL	CLAIRTON, PA	40 18 15	079 52 43	14762	4	2	.019152	.023040	.005760
12	ARCO	HOUSTON, TX	29 42 17	095 16 01	12960	5	3	.012557	.028666	.014269
							4	5.507568	.210816	1.001376
13	SUN	MARCUS HOOK, PA	39 48 50	075 24 51	13739	6	3	.014904	.029808	.014904
14	EXXON	BAYTOWN, TX	29 44 50	095 01 00	12906	7	4	5.236704	.200448	.952128
15	TENNECO	CHALMETTE, LA	30 03 30	089 58 30	12958	7	4	3.400875	.130175	.618309
17	SUN	CORPUS CHRISTI, TX	27 50 00	097 31 25	12925	8	4	4.213280	.161279	.766077
							5	.012744	.0065336	.006336

TABLE 29-29. (Concluded)

No.	Company	Site	Latitude	Longitude	Star Station	Plant* Type	Source+ Type	Emissions (GM/SEC)		
								Process	Storage	Fugitive
18	CHARTER	HOUSTON, TEXAS	29 42 50	095 15 12	12906	9	5	.006048	.003024	.003024
19	ALLIED	EL SEGUNDO, CA	33 56 30	118 26 35	23129	10	6	.052416	.007488	.014976
20	BASF	KEARNY, NJ	40 45 53	074 09 03	04739	10	6	.215712	.030816	.061632
21	KOPPERS	CCICERO IL	41 48 44	087 45 04	14855	10	6	.338692	.048383	.096766
22	CHEVRON	RICHMOND, CA	37 56 12	122 20 48	23239	10	6	.072574	.010368	.020736
23	STEPAN	MILLSDALE, IL	41 26 03	088 09 48	94846	10	6	.143135	.020448	.040896

TABLE 29-29 (Concluded)

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* Plant types:

Type 1: Plant produces mixed xylene (gasoline pyrolysis)
Type 2: Plant rpoduces mixed xylene (gasoline pyrolysis) and phthalic anhydride
Type 3: Plant produces mixed xylene (gasoline pyrolysis) and o-xylene
Type 4: Plant produces mixed xylene (coal-derived)
Type 5: Plant produces mixed xylene (toluene disproportionation),o-xylene and ethylb-enzene
Type 6: Plant produces mixed xylene (toluene disproportionation)
Type 7: Plant produces o-xylene
Type 8: Plant produces o-xylene and ethylbenzene
Type 9: Plant produces ethylbenzene
Type 10: Plant produces phthalic anyydride

† Source types:

Type 1: Mixed xylene production (gasoline pyrolysis)
Type 2: Mixed xylene production (coal-derived)
Type 3: Mixed xylene production (toluene disproportionation)
Type 4: o-xylene isolation
Type 5: Ethylbenzene isolation
Type 6: Phthalic anhydride production

TABLE 29-30. EXPOSURE AND DOSAGE OF o-XYLENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed* (persons)	Dosage [(ug/m^3) . persons]
25	0	0
10	0	0
5	4,572	29,000
2.5	13,188	60,300
1	66,322	141,000
0.5	172,562	13,000
0.25	439,744	303,000
0.1	1,270,307	432,000
0.05	2,776,807	538,000
0.025	4,047,056	586,000
0.01	6,501,317	624,000
0.005	9,625,488	646,000
0.0025	12,691,212	657,000
2.74×10^{-5}	21,041,612	664,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 29-31. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF O-XYLENE

Region	Mixed Xylene Production (Catalytic Reforming)		Gasoline Marketing	
	Emissions/Site (gm/sec)	Number of Sites	Emissions/Site (gm/sec)	Number of Sites
New England	0	0	0.00014	11,105
Middle Atlantic	0.144	17	0.00014	28,383
East North Central	0.158	28	0.00014	42,270
West North Central	0.0667	16	0.00014	23,304
South Atlantic	0.0745	5	0.00014	37,286
East South Central	0.137	8	0.00014	16,313
West South Central	0.180	71	0.00014	28,336
Mountain	0.0345	23	0.00014	12,815
Pacific	0.130	33	0.00014	26,647

TABLE 29-32. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF o-XYLENE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)			Dosage [$10^6(\mu g/m^3 \cdot$ persons)]		
	Mixed Xylene Production	Gasoline Marketing	U.S Total	Mixed Xylene Production	Gasoline Marketing	U.S. Total
2.5	0.84	0	0.84	2.5	0	2.5
1	22	0	22	33	0	33
0.5	125	0	125	103	0	103
0.25	388	0	388	194	0	194
0.1	1,690	0	1,690	387	0	387
0.05	4,110	0	4,110	545	0	545
0.025	--	--	--	716	0	716
0.01	--	--	--	954	29	983
0.005	--	--	--	1,150	109	1,260
0.0025	--	--	--	1,380	251	1,630
0.001	--	--	--	1,590	625	2,010
0.0005	--	--	--	1,640	590	2,230
0.00025	--	--	--	1,640	786	2,430
0.0001	--	--	--	1,650	1,150	2,790
0	--	--	--	1,650	3,260	4,910

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 29-33. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF o-XYLENE

Parameter	Value
Daytime decay rate (K_d)	5.6 x 10^{-5} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	1830 gm/sec
Paint/coating solvent emissions	1246 gm/sec
Adhesive emissions	277 gm/sec
Agricultural pesticide emissions	195 gm/sec
Miscellaneous	162 gm/sec
Nationwide mobile source emissions (E_M)	1936 gm/sec
Chemical (automobile) emissions	192 gm/sec
Motor vehicle gasoline evaporation	28 gm/sec
Motor vehicle exhaust emissions	1716 gm/sec
Ratio of truck emissions to auto emissions (R_M)	3

TABLE 29-34. o-XYLENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
10.000000	505140	6729382.4	0.	72.5	27.5	100.0	0.	0.
5.000000	505140	6729382.4	0.	72.5	27.5	100.0	0.	0.
2.500000	19771703	79754865.4	0.	67.4	32.6	100.0	0.	0.
1.000000	68426035	154609889.4	0.	59.9	40.1	97.1	1.5	1.4
.500000	135515314	204701332.8	0.	58.7	41.3	93.1	3.2	3.7
0.	158679135	212475034.1	0.	58.4	41.6	91.2	3.4	5.5

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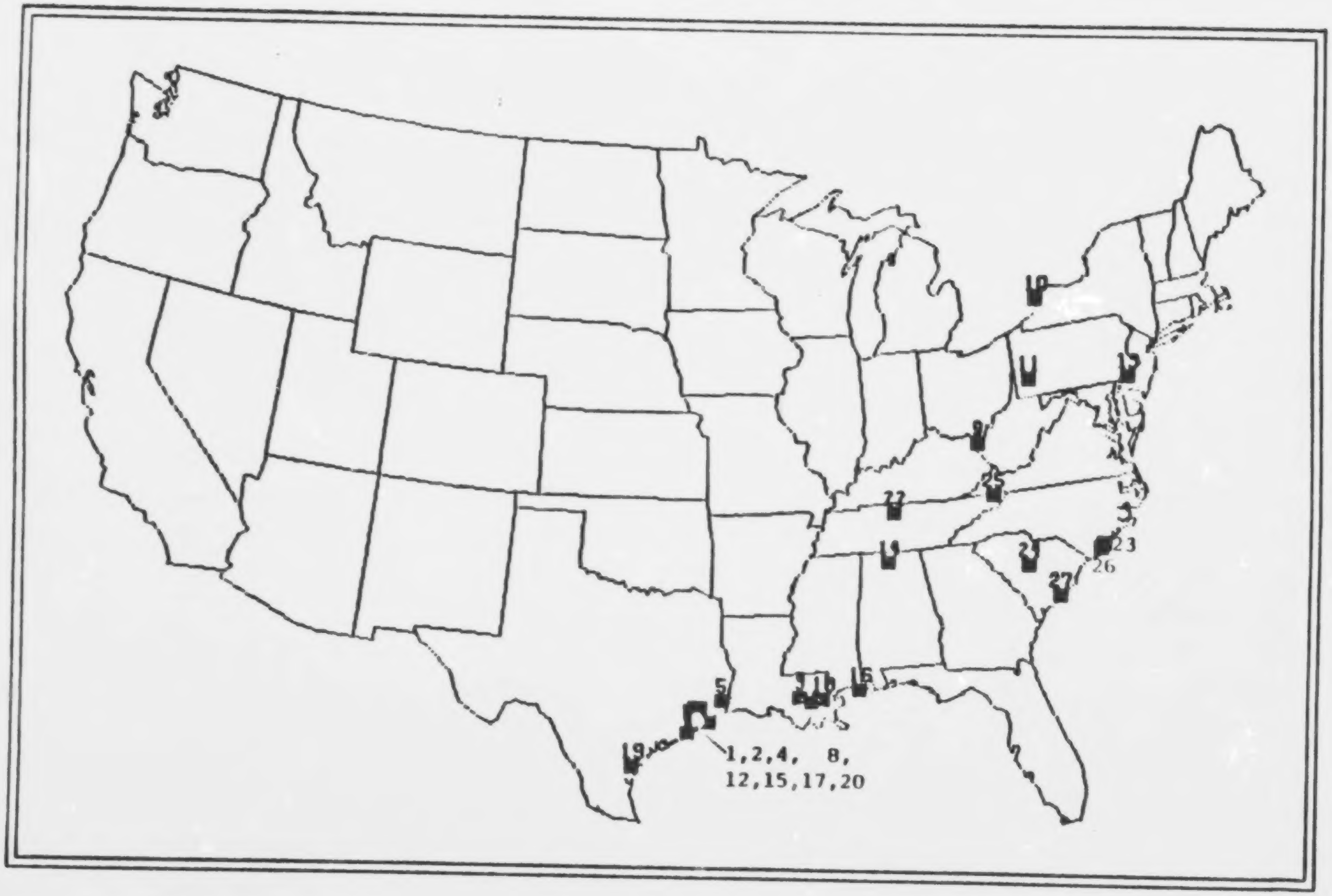
TABLE 20-35. EXPOSURE AND DOSAGE SUMMARY OF o-XYLENE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) - persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
25	0	0	0	0	0	0	0	0
10	0	0	0	0	0	0	6,729,382	6,729,382
5	4,572	--	0	4,572	29,000	--	6,729,382	--
2.5	13,188	840	19,771,703	19,785,731	60,300	2,500	79,754,865	79,817,665
1	66,322	22,000	68,426,035	68,514,357	141,000	33,000	154,689,889	154,863,889
0.5	172,562	125,000	135,515,319	13,739,093	213,000	103,000	204,701,332	205,017,332
0.25	439,744	388,000	--	--	303,000	194,000	--	--
0.1	1,270,307	1,690,000	--	--	432,000	387,000	--	--
0	21,041,612	--	--	--	664,000	4,910,000	212,475,000	218,049,000

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.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1,2,4, 8,
12,15,17,20
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FIGURE 29-3. SPECIFIC POINT SOURCES OF p-XYLENE EMISSIONS

Table 29-36. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-XYLENE

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC) PROCESS	STORAGE	FUGITIVE
1	ARCO	CHANNELVIEW, TX	29 50 04	095 06 43	12906	1	1	.041616	.178127	.017813
2	DOW	FREEPORT, TX	28 59 30	095 23 35	12923	1	1	.012816	.054864	.005486
3	EXXON	BATON ROUGE,LA	30 09 10	090 54 20	13970	1	1	.009259	.039745	.003974
4	GULF	CEDAR BAYOU, TX	29 49 29	094 55 10	12923	1	1	.006221	.026640	.002664
5	MOBILE	BEAUMONT, TX	30 04 14	094 03 40	12917	1	1	.004550	.019440	.001944
7	UNION CARBIDE	TAFT, LA	29 58 00	090 27 00	12970	1	1	.023040	.098782	.009878
8	SHELL	DEER PARK, TX	29 42 55	095 07 34	12906	2	1	.007056	.030240	.003024
							4	1.313293	.218880	.276481
9	ASHLAND	CATLETTSBURG, KY	38 22 39	082 35 58	13866	3	2	.015696	.018720	.004608
10	ASHLAND	N. TONAWANDA, NY	42 59 45	078 55 27	14747	3	2	.008424	.010080	.002520
11	U.S. STEEL	CLAIRTON, PA	40 18 15	079 52 43	14762	3	2	.015696	.018720	.004608
12	ARCO	HOUSTON, TX	29 42 17	095 16 01	12960	4	3	.011669	.023338	.011669
							4	4.333824	.722304	.912884
13	SUN	MARCUS HOOK, PA	39 48 45	075 24 51	13789	5	3	.012096	.024336	.012096
14	AMOCO	DECATUR, AL	34 36 12	086 58 42	13882	6	4	7.331423	1.221906	1.543460
								15.151001	.656138	.417548
15	AMOCO	TEXAS CITY, TX	29 21 40	094 55 50	12906	7	4	2.606804	0.434463	0.548796
16	CHEVRON	PASCAGOULA, MS	30 19 04	088 28 37	13820	7	4	3.972602	.662100	.836346
17	EXXON	BAYTOWN, TX	29 44 50	095 01 00	12906	7	4	5.056128	.842688	1.064448
18	TENNECO	CHALMETTE, LA	30 03 30	089 58 30	12958	7	4	1.510274	.251709	.317954

Table 29-36. EMISSIONS AND METEOROLOGICAL STATIONS OF SPECIFIC POINT SOURCES OF p-XYLENE (concluded)

NO.	COMPANY	SITE	LATITUDE	LONGITUDE	STAR STATION	PLANT* TYPE	SOURCE+ TYPE	EMISSIONS (GM/SEC)		
								PROCESS	STORAGE	FUGITIVE
19	SUN	CORPUS CHRISTI, TX	29 50 00	097 31 25	12925	8	4	4.694951	.782502	.988426
							5	.012816	.006336	.006336
20	CHARTER	HOUSTON, TX	29 42 50	095 15 12	12906	9	5	.006048	.003024	.003024
22	DUPONT	OLD HICKORY, TN	36 16 24	086 34 12	13897	10	6	.511067	.117935	.275184
23	DUPONT	WILMINGTON, NC	34 10 00	077 56 06	13717	10	6	1.257959	.268702	.626966
24	EASTMAN KODAK	COLUMBIA, SC	33 59 50	081 04 17	13883	10	6	.466102	.107569	.250992
25	EASTMAN KODAK	KINSPORT, TN	36 31 41	082 12 22	13877	10	6	.466102	.107569	.250992
26	HERCOFINA	WILMINGTON, NC	34 19 27	077 46 56	13717	11	6	1.211187	.279503	.652175
							7	3.877156	.167903	.106849
27	AMOCO	COPPER RIVER, SC	32 45 57	079 56 28	13717	12	7	9.889597	.428292	.272550

TABLE 29-36 (Concluded)

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* Plant Types:

Type 1: Plant produces mixed xylene (gasoline pyrolysis)
Type 2: Plant produces mixed xylene (gasoline pyrolysis) and p-xylene
Type 3: Plant produces mixed xylene (coal-derived)
Type 4: Plant produces mixed xylene (toluene disproportionation), p-xylene and ethylbenzene
Type 5: Plant produces mixed xylene (toluene disproportionation)
Type 6: Plant produces p-xylene and terephthalic acid
Type 7: Plant produces p-xylene
Type 8: Plant produces p-xylene and ethylbenzene
Type 9: Plant produces ethylbenzene
Type 10: Plant produces dimethyl terephthalate
Type 11: Plant produces dimethyl terephthalate and terephthalic acid
Type 12: Plant produces terephthalic acid

Source types:

Type 1: Mixed xylene production (gasoline pyrolysis)
Type 2: Mixed xylene production (coal-derived)
Type 3: Mixed xylene production (toluene disproportionation)
Type 4: p-Xylene isolation
Type 5: Ethylbenzene isolation
Type 6: Terephthalic acid production

TABLE 29-37. EXPOSURE AND DOSAGE OF p-XYLENE RESULTING FROM SPECIFIC POINT SOURCE EMISSIONS

Concentration Level (ug/m^3)	Population Exposed (persons)	Dosage [(ug/m^3) . persons]
250	-	-
100	59	6,480
50	240	18,300
25	1,523	62,600
10	5,871	125,000
5	22,126	232,000
2.5	49,090	325,000
1	138,977	460,000
0.5	280,119	561,000
0.25	540,985	649,000
0.1	1,386,718	778,000
0.05	2,532,162	860,000
2.63×10^{-5}	10,150,367	920,000

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*The lowest annual average concentration occurring within 20 km of the specific point source.

TABLE 29-38. EMISSIONS RATES AND NUMBER OF GENERAL POINT SOURCES OF p-XYLENE

Region	Mixed Xylene Production (Catalytic Reforming)		Gasoline Marketing	
	Emissions/Site (gm/sec)	Number of sites	Emissions/Site (gm/sec)	Number of Sites
New England	0.0	0	0.00014	11,105
Middle Atlantic	0.117	17	0.00014	28,383
East North Central	0.129	28	0.00014	42,270
West North Central	0.0543	16	0.00014	23,304
South Atlantic	0.0607	5	0.00014	37,286
East South Central	0.111	8	0.00014	16,313
West South Central	0.146	71	0.00014	28,336
Mountain	0.0281	23	0.00014	12,815
Pacific	0.106	33	0.00014	26,647

TABLE 29-39. EXPOSURE AND DOSAGE RESULTING FROM EMISSIONS FROM GENERAL POINT SOURCES OF p-XYLENE

Concentration Level ($\mu g/m^3$)	Population Exposed (10^3 persons)			Dosage [10^6($\mu g/m^3$) • persons]		
	Mixed Xylene Production	Gasoline Marketing	U.S Total	Mixed Xylene Production	Gasoline Marketing	U.S. Total
1	15	0	15	21	0	21
0.5	91	0	91	72	0	72
0.25	339	0	339	158	0	158
0.1	1,650	0	1,650	341	0	341
0.05	3,410	0	3,410	464	0	464
0.025	--	--	--	663	0	663
0.01	--	--	--	854	38	892
0.005	--	--	--	1,060	124	1,180
0.0025	--	--	--	1,270	271	1,540
0.0001	--	--	--	1,470	458	1,930
0.0005	--	--	--	1,530	645	2,180
0.00025	--	--	--	1,550	843	2,390
0.0001	--	--	--	1,550	1,240	2,790
0.00005	--	--	--	1,550	1,550	3,100
0	--	--	--	1,550	3,410	4,960

NOTE: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

TABLE 29-40. MAJOR PARAMETERS FOR ESTIMATING EXPOSURE/DOSAGE RESULTING FROM AREA SOURCE EMISSIONS OF p-XYLENE

Parameter	Value
Daytime decay rate (K_d)	1.12×10^{-4} sec^{-1}
Nighttime decay rate (K_n)	0
Hanna-Gifford coefficient (C)	225
Nationwide heating source emissions (E_H)	0
Nationwide nonheating stationary source emissions (E_N)	1488 gm/sec
Paint/coating solvent emissions	1015 gm/sec
Adhesive emissions	185 gm/sec
Agricultural pesticide emissions	156 gm/sec
Miscellaneous	132 gm/sec
Nationwide mobile source emissions (E_M)	1745 gm/sec
Chemical (automobile) emissions	156 gm/sec
Motor vehicle gasoline evaporation	28 gm/sec
Motor vehicle exhaust emissions	1561 gm/sec
Ratio of truck emissions to auto emissions (R_M)	3

TABLE 29-41. p-XYLENE EXPOSURE AND DOSAGE RESULTING FROM AREA SOURCE EMISSIONS

EXPO LEVEL (UG/(M)3)	POPULATION (PERSON)	DOSAGE (UG/(M)3-PERSON)	PERCENTAGE OF CONTRIBUTION			PERCENTAGE OF DISTRIBUTION		
			HEATING	STATIONARY	MOBILE	CITY TYPE 1	CITY TYPE 2	CITY TYPE 3
10.000000	505140	5580616.9	0.	70.4	29.6	100.0	0.	0.
5.000000	505140	5580616.9	0.	70.4	29.6	100.0	0.	0.
2.500000	12853644	46813161.7	0.	68.6	31.4	100.0	0.	0.
1.000000	52650656	109234512.0	0.	58.6	41.4	97.5	.9	1.6
.500000	121944638	157185626.7	0.	56.4	43.6	93.7	3.2	3.1
0.	158679135	169872766.6	0.	55.7	44.3	90.6	3.5	5.8

TABLE 29-42. EXPOSURE AND DOSAGE SUMMARY OF p-XYLENE

Concentration Level (ug/m^3)	Population Exposed (persons)				Dosage [(ug/m^3) . persons]			
	Specific Point Source	General Point Source	Area Source	U.S. Total	Specific Point Source	General Point Source	Area Source	U.S. Total
250	-	0	0	-	-	0	0	-
100	59	0	0	59	6,480	0	0	6,480
50	240	0	0	240	18,300	0	0	18,300
25	1,523	0	0	1,523	62,600	0	0	62,600
10	5,871	0	0	511,011	125,000	0	5,580,616	5,705,616
5	22,126	0	505,140	527,266	232,000	0	5,580,616	--
2.5	49,090	0	505,140	--	325,000	0	46,813,161	--
1	138,977	15,000	12,853,644	--	--	21,000	109,234,512	--
0.5	280,119	91,000	52,650,656	--	--	72,000	157,185,626	--
0.25	540,985	339,000	121,944,638	--	--	158,000	--	--
0.25		1,650,000	--	--	--	158,000	--	--
0.1	--	3,410,000	--	--	--	341,000	--	--
0.05	--		--	--	--	464,000	--	--
0.025	--	--	--	--	--	663.000	--	--
0	10,150,367	--	158,679,135	--	920,000	4,960,000	169,872,766	175,752,766

Note: The use of -- as an entry indicates that the incremental E/D is not significant (relative to last entry or relative to entry in another column at the same row) or that the exposure of the same population may be counted in another column.

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